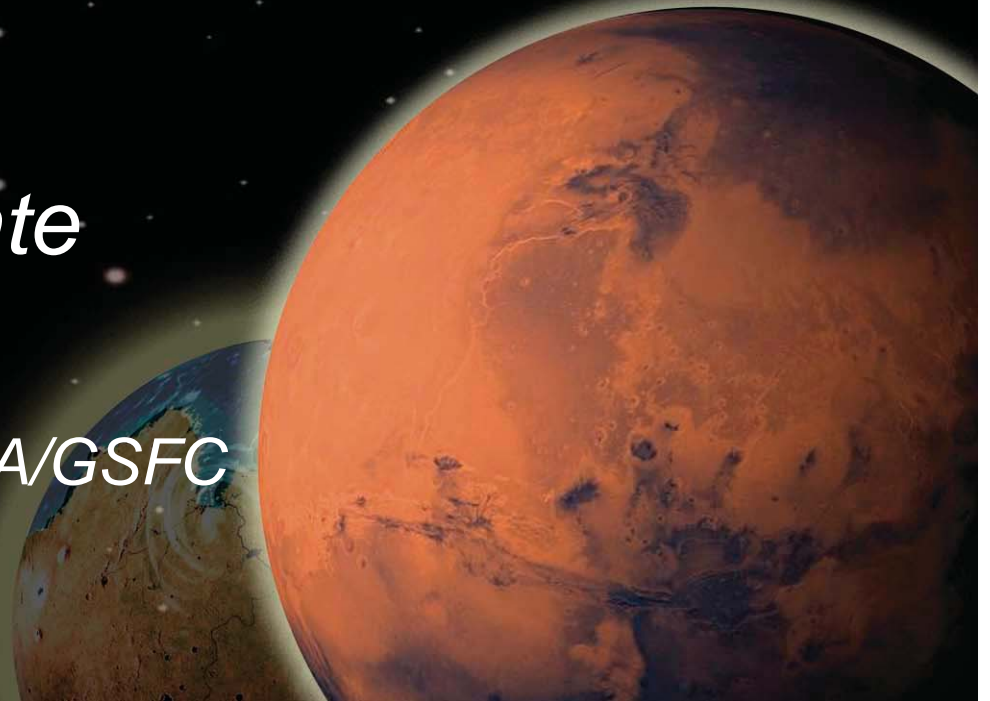
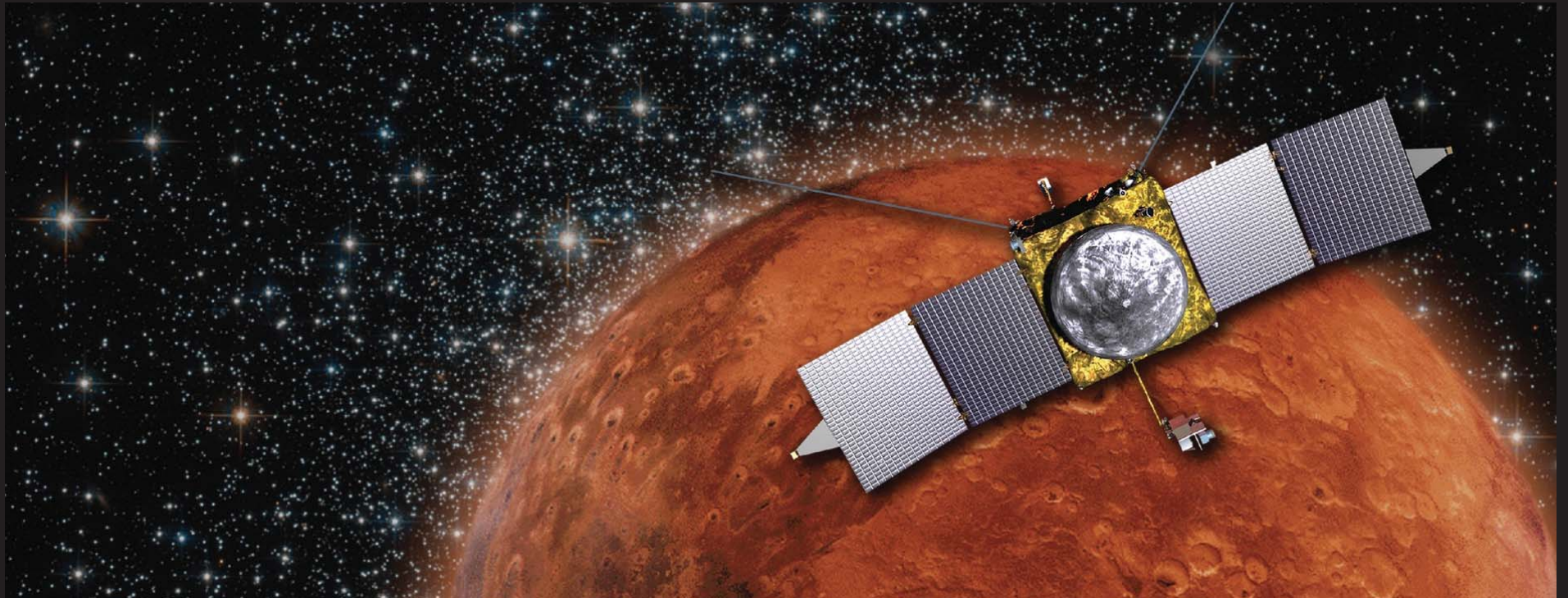


*The MAVEN Mission:  
Exploring Mars' Climate  
History*

*Sandra Cauffman, NASA/GSFC*



# *The Science*

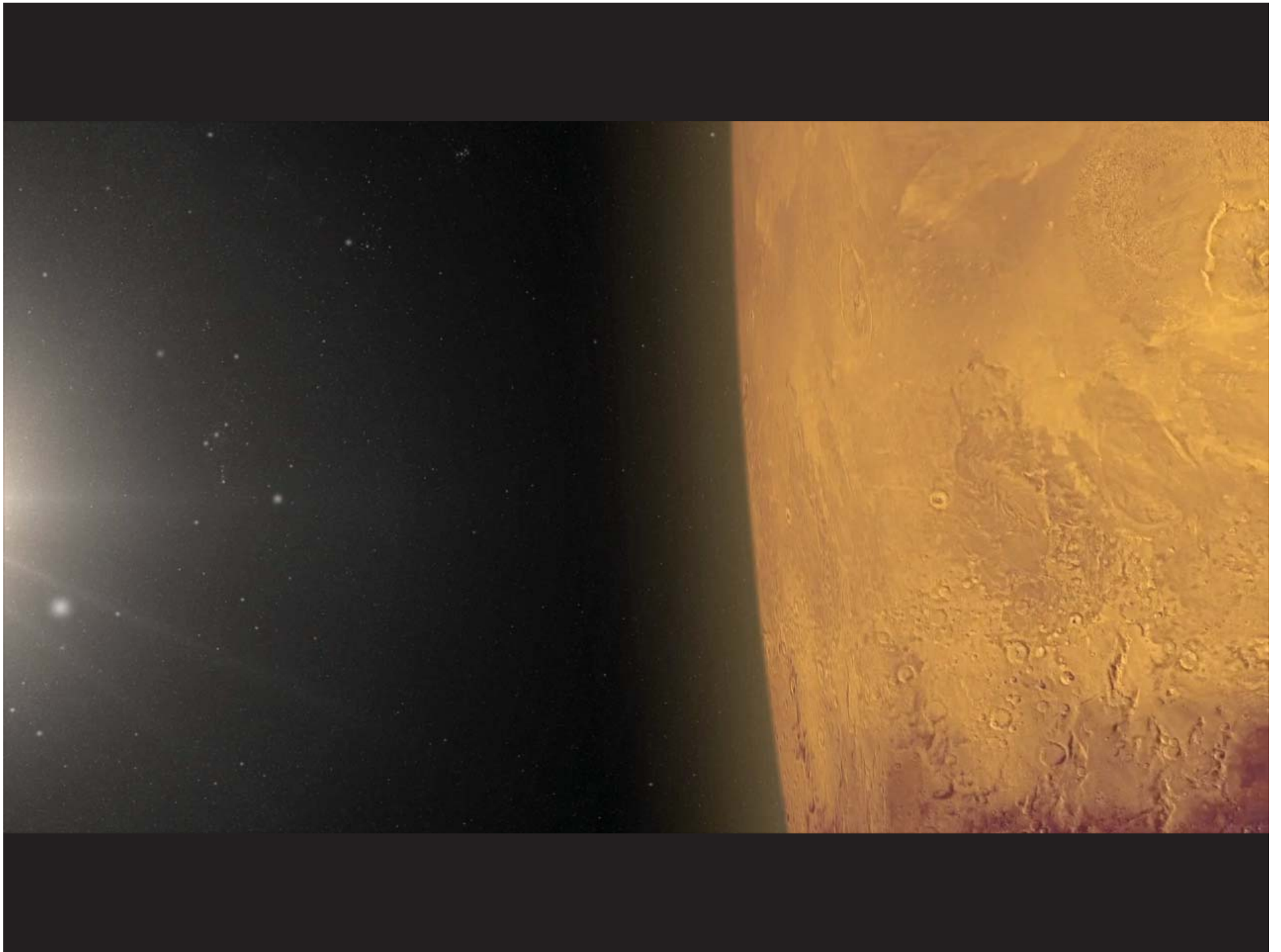


*Earth*



*Mars*

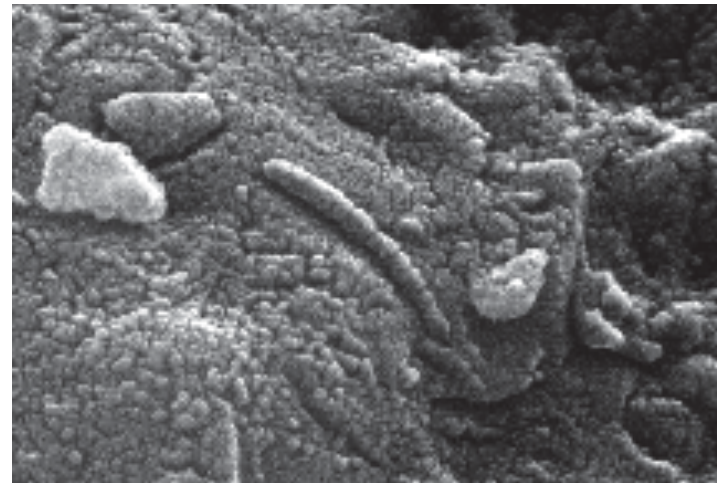




# Overarching Question: Did Mars Ever Have Life?

Mars appears to meet or have met all of the environmental requirements for the occurrence of life:

- Liquid water
- Access to the biogenic elements
- Source of energy to drive metabolism



*Did Mars ever have life?*

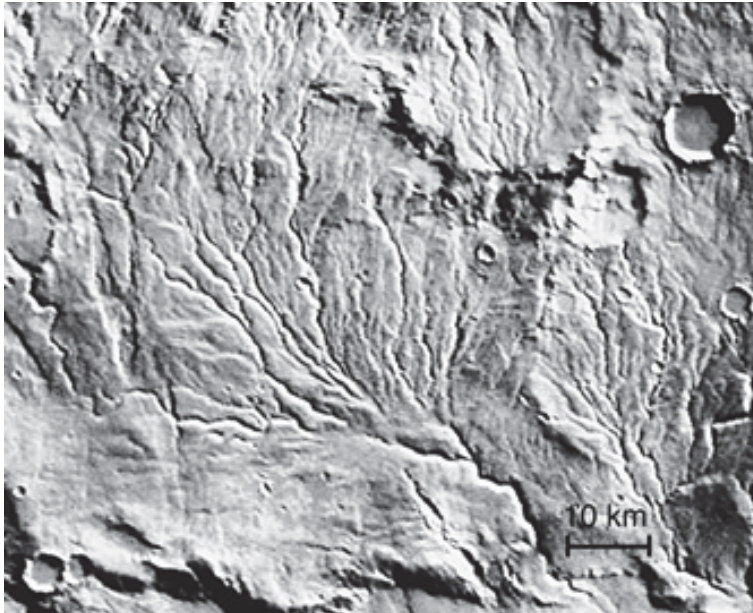
*How did any life interact with its planetary environment?*

*How has the habitability of Mars changed over time?*

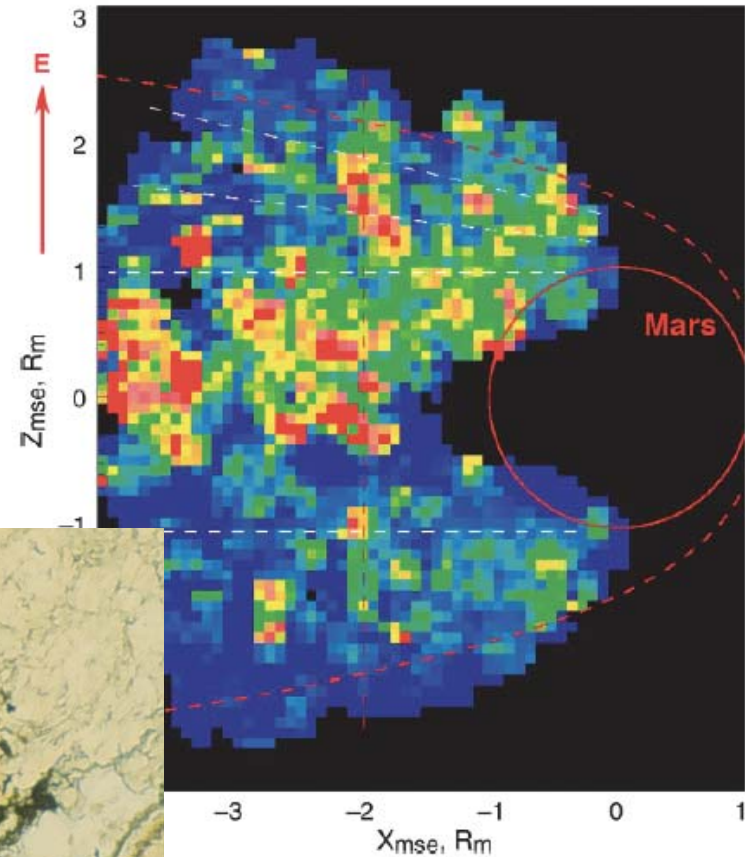
# *Evidence for Surface Water on Ancient Mars*

## *Where Did the Water Go? Where Did the CO<sub>2</sub> Go?*

*Abundant evidence for ancient water*

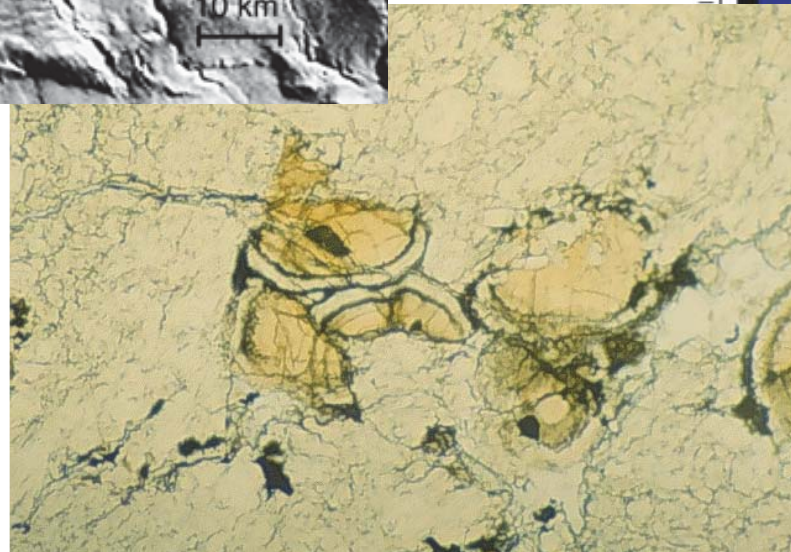


*Volatiles can be lost to space*



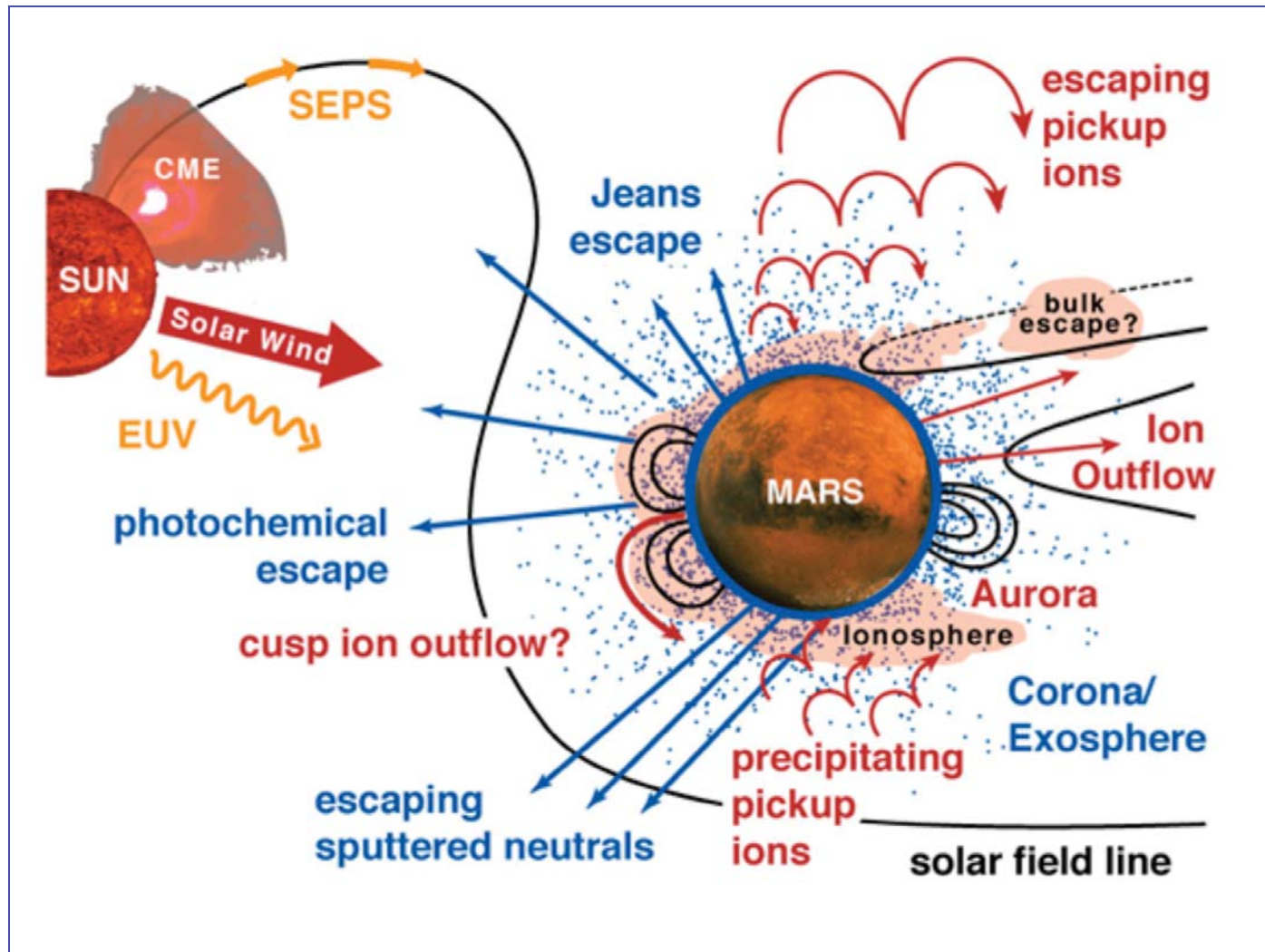
*Escaping ions detected from Mars Express*

*Volatiles can go into the crust*



*Carbonate deposits in a Martian meteorite*

# MAVEN Will Allow Us to Understand Escape of Atmospheric Gases to Space



# The Solar Wind is Able to Strip Off Gas from the Top of the Atmosphere



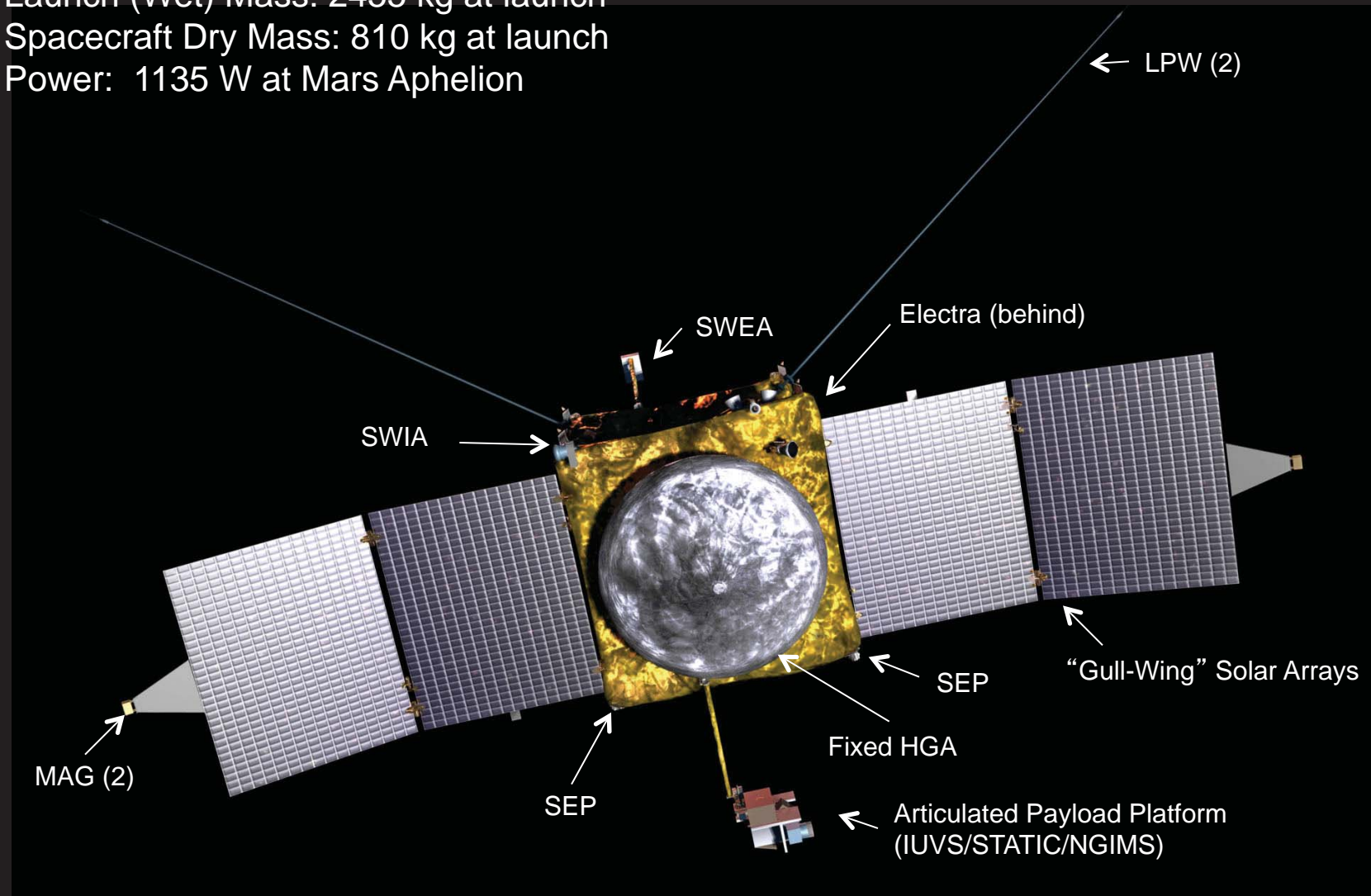
Credit:  
NASA/Nagoya University

# *The Mission*



# The MAVEN Spacecraft

- Launch (Wet) Mass: 2455 kg at launch
- Spacecraft Dry Mass: 810 kg at launch
- Power: 1135 W at Mars Aphelion



# *The MAVEN Science Instruments:*

## *Sun, Solar Wind, Solar Storms*



SWEA



SEP

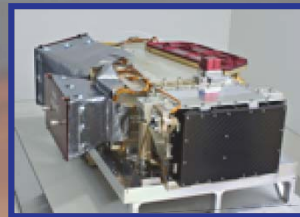


EUV



SWIA

## *Neutrals and Ions Plus Evolution*



IUVS



NGIMS

## *Ion-Related Properties and Processes*



STATIC



MAG



LPW

# The Spacecraft Undergoes Final Testing

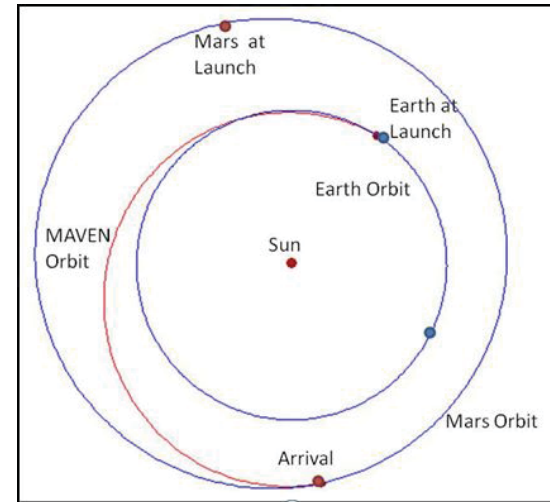


# MAVEN Mission Architecture



**Launched on 18  
Nov. 2013,  
first day of its  
20-day launch  
period  
Launch Vehicle:  
Atlas – V 401**

## Ten-Month Type-II Ballistic Cruise to Mars



**Orbit Insertion: 22 Sept 02:00, 2014 UTC.  
33 minute rocket burn**



## One Year of Science Operations



# MAVEN's Path To Mars

19 Nov 2013 06:30:00.000

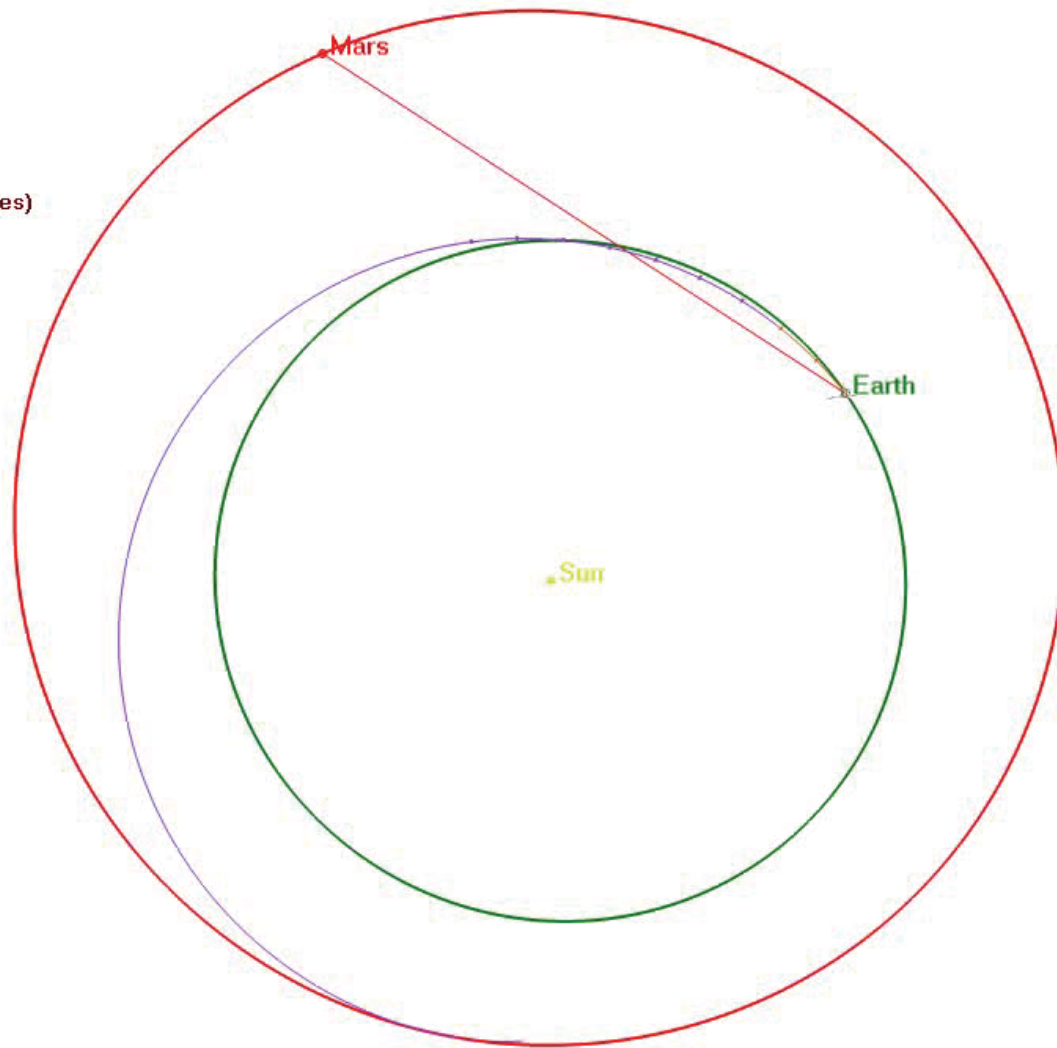
Days to Mars Arrival (MisElap): -306/14:00:00.000

## MAVEN Range and Velocity (units of Kilometers)

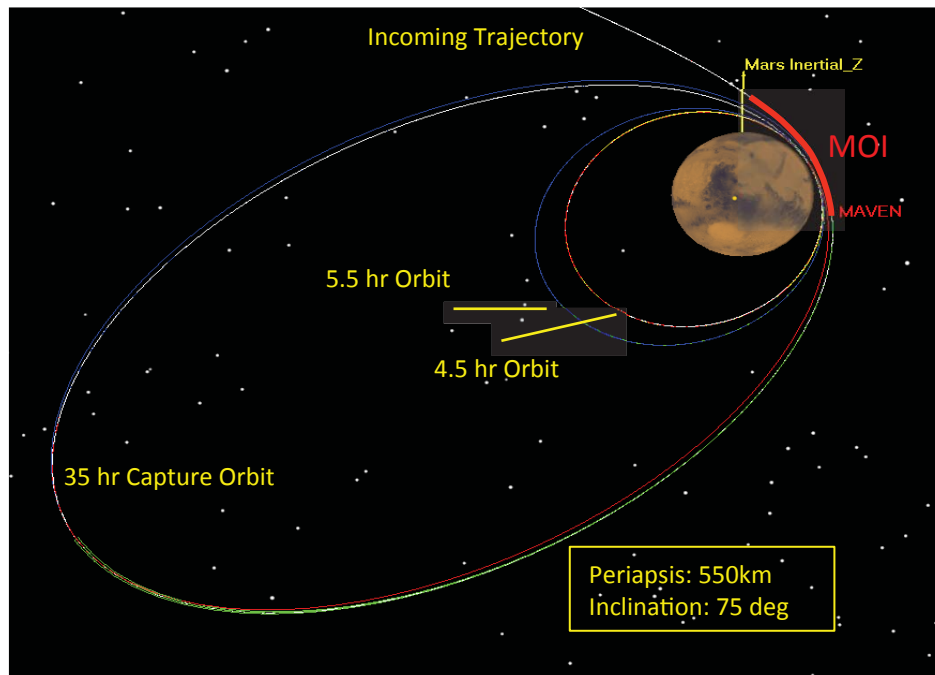
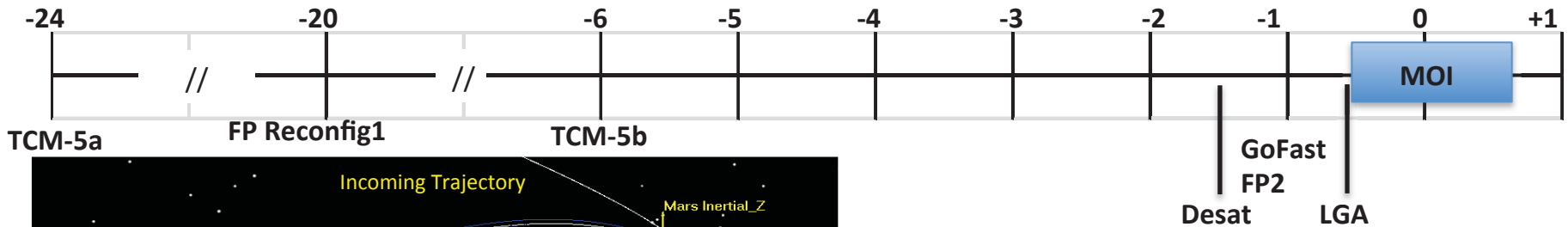
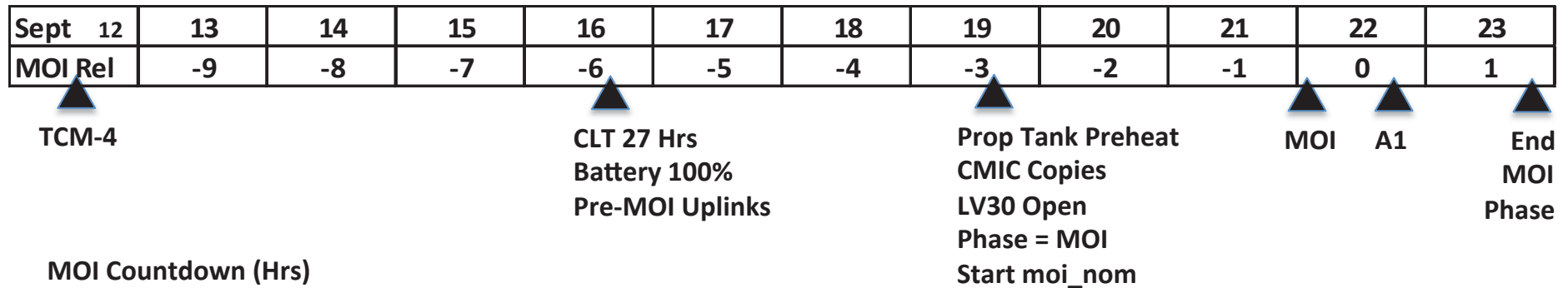
Earth\_Range (km): 192293  
Velocity\_wrt\_Earth (km/sec): 4.045  
Mars\_Range (km): 264525423  
Velocity\_wrt\_Mars (km/sec): 33.724  
Sun\_Range (km): 147718010  
Velocity\_wrt\_Sun (km/sec): 33.019

## MAVEN Range and Velocity (units of Miles)

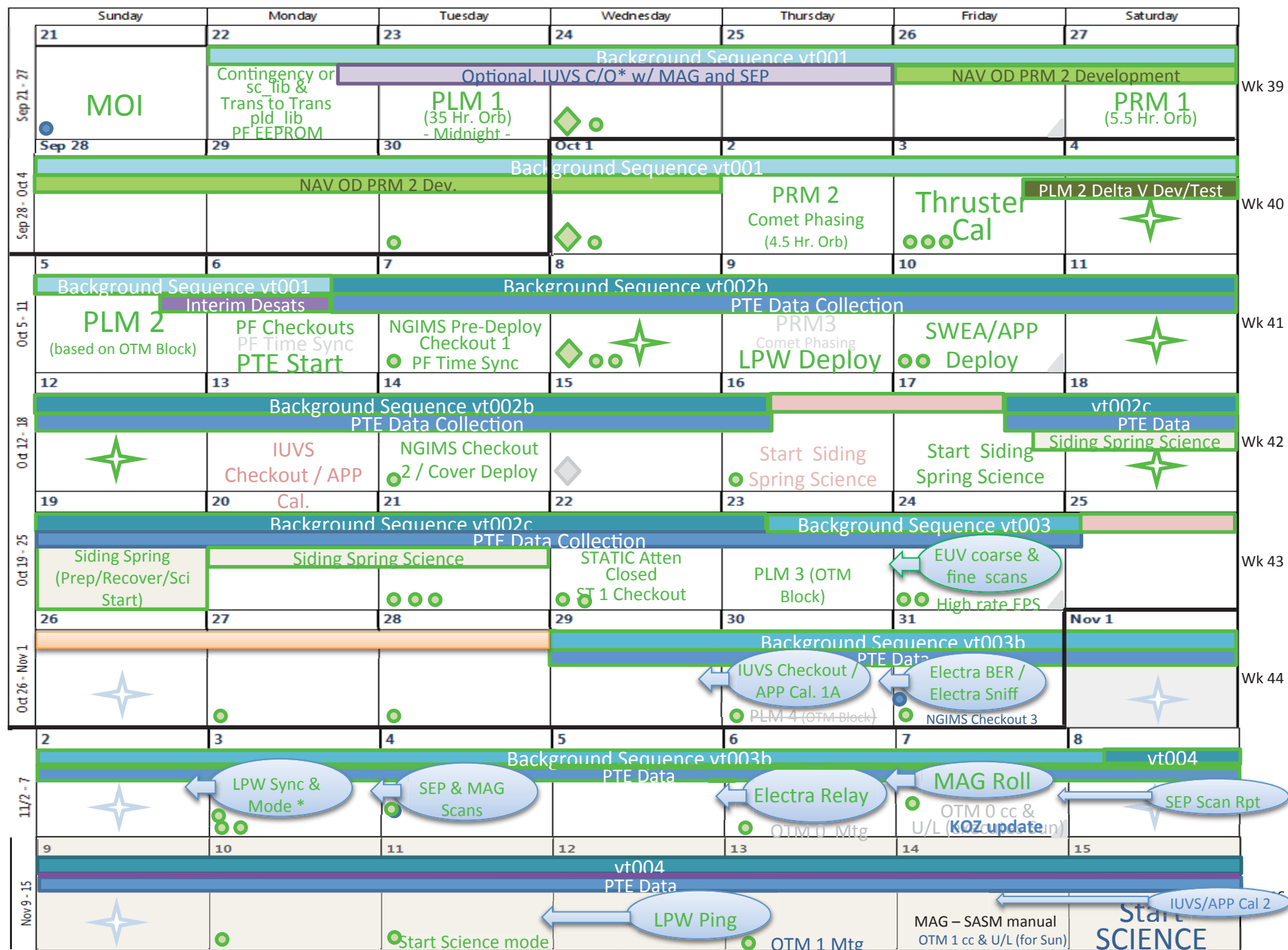
Earth\_Range (mi): 119485  
Velocity\_wrt\_Earth (mi/sec): 2.513  
Mars\_Range (mi): 164368478  
Velocity\_wrt\_Mars (mi/sec): 20.955  
Sun\_Range (mi): 91787716  
Velocity\_wrt\_Sun (mi/sec): 20.517



# Mars Orbit Insertion Preparations



- MOI occurred on 9/21/14 (EDT)
- Sequence activated 3 days out
- Emergency TCM 5a and 5b opportunities at MOI-24 hours and MOI-6 hours
- Configured for GoFast Recovery (MOI-1 hour)
- In contact with Earth during the entire burn sequence (at 40 bps)
- Primary operations at LM-Denver, backup operations at Goddard

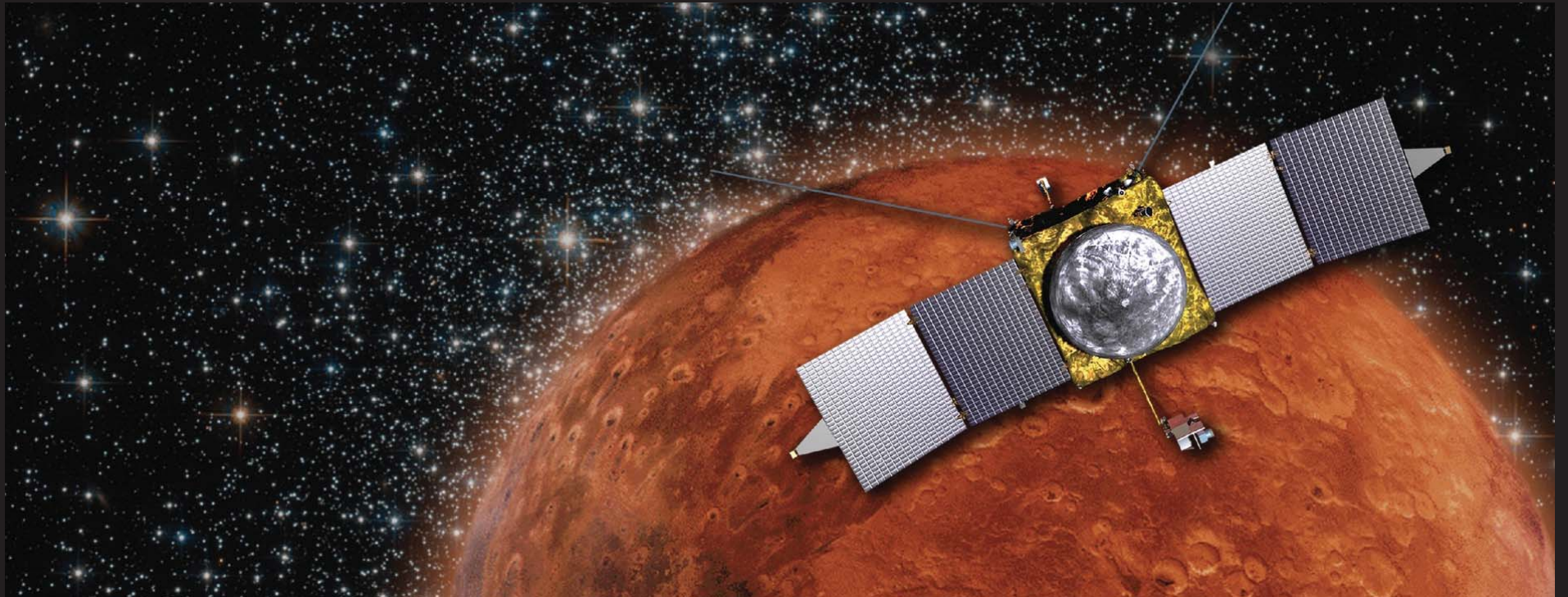


◆ Planned for Dust Off Reviews ★ Margin Date – No planned SC Commanding (contingency) ● Command Conference (Approx. Dates) ○ Out of Contact

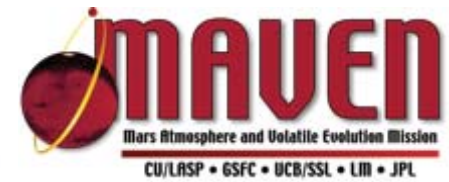
## The MAVEN Team that Got Us Here



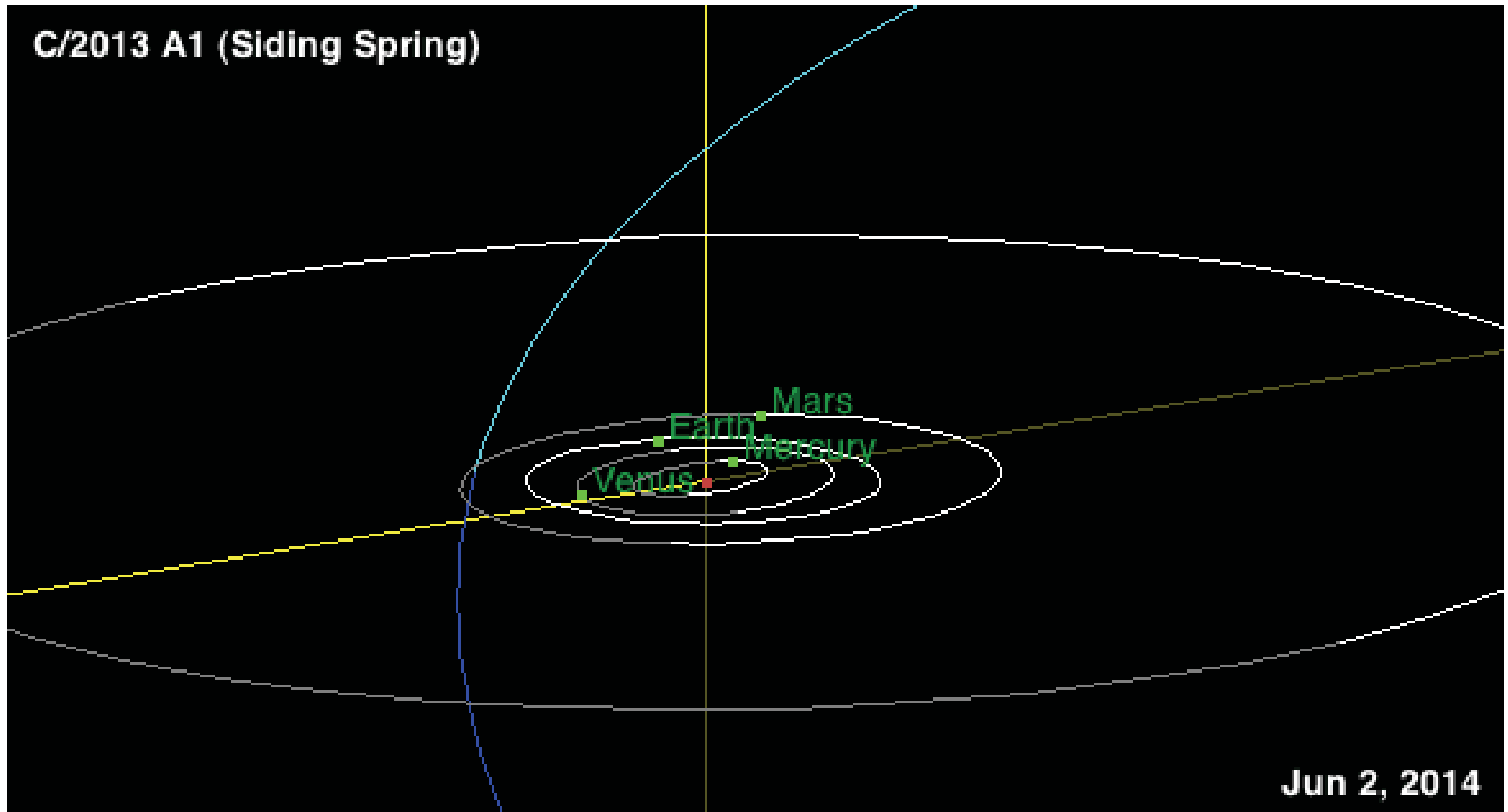
# *The Comet*



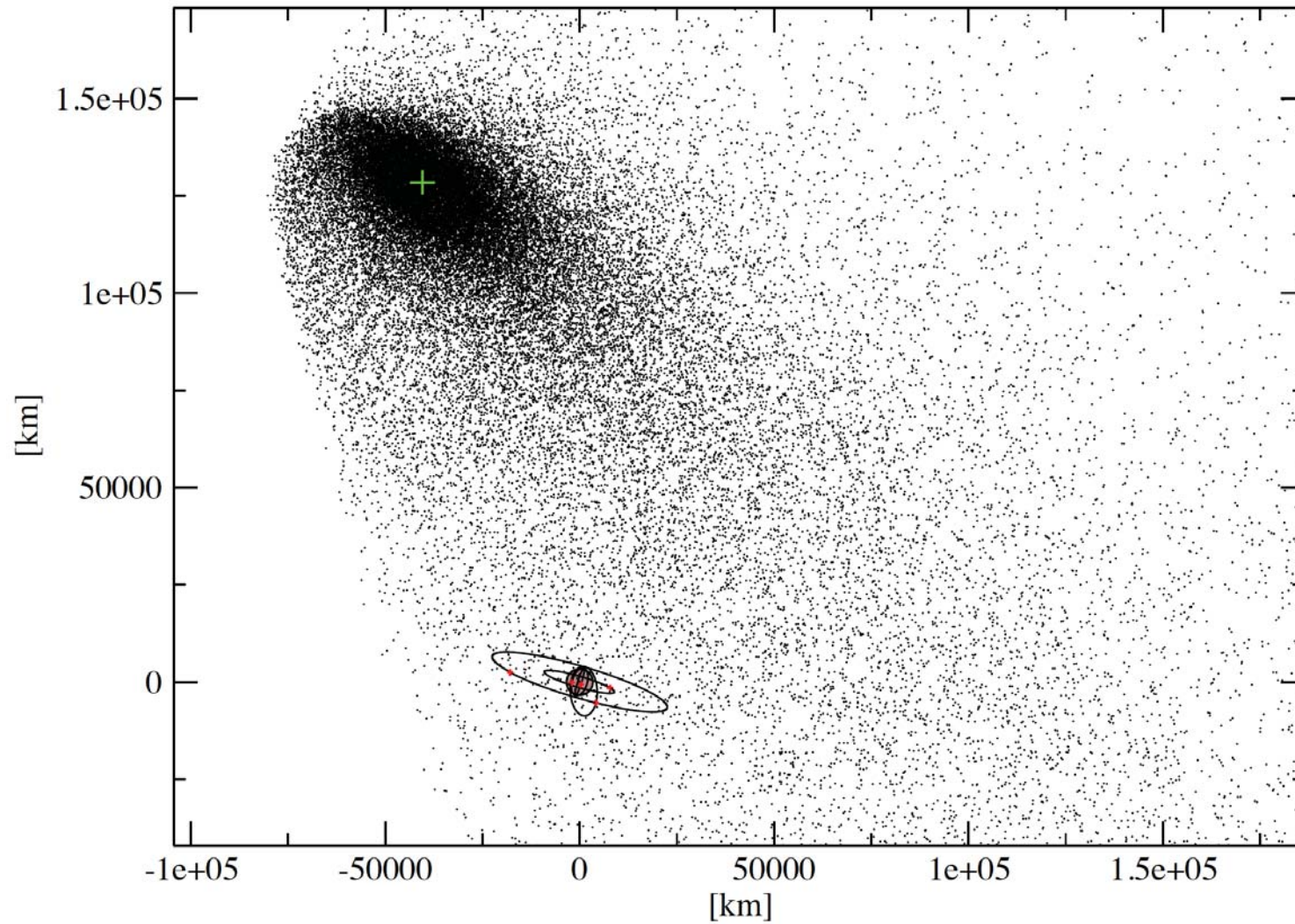
# Cosmic Serendipity



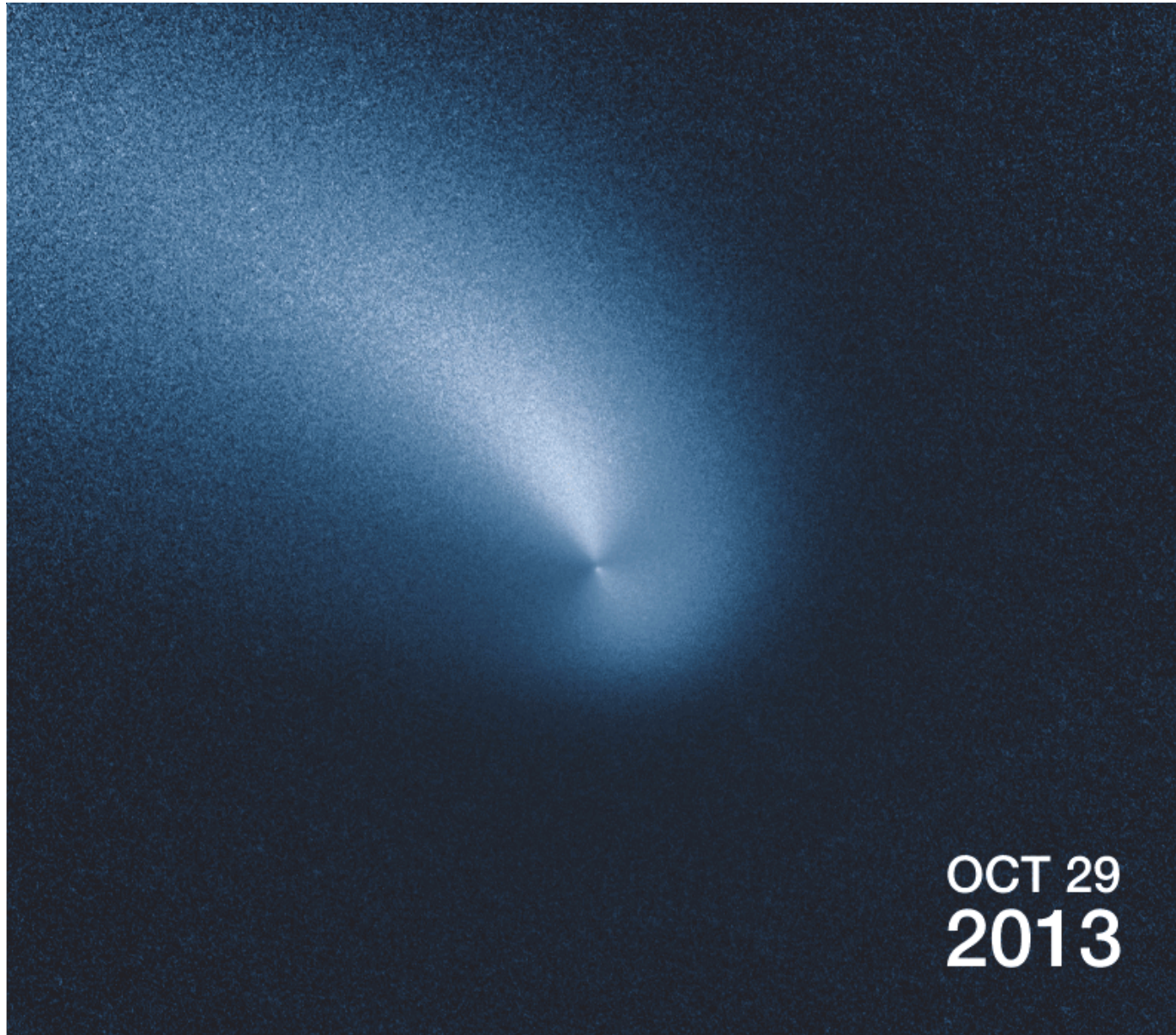
C/2013 A1 (Siding Spring)



# The Problem



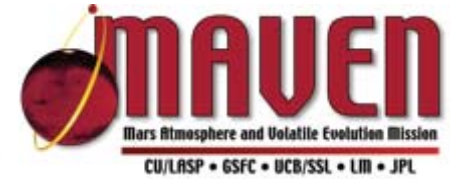
# HST Image of Siding Spring



What you  
see in this  
image is  
dust

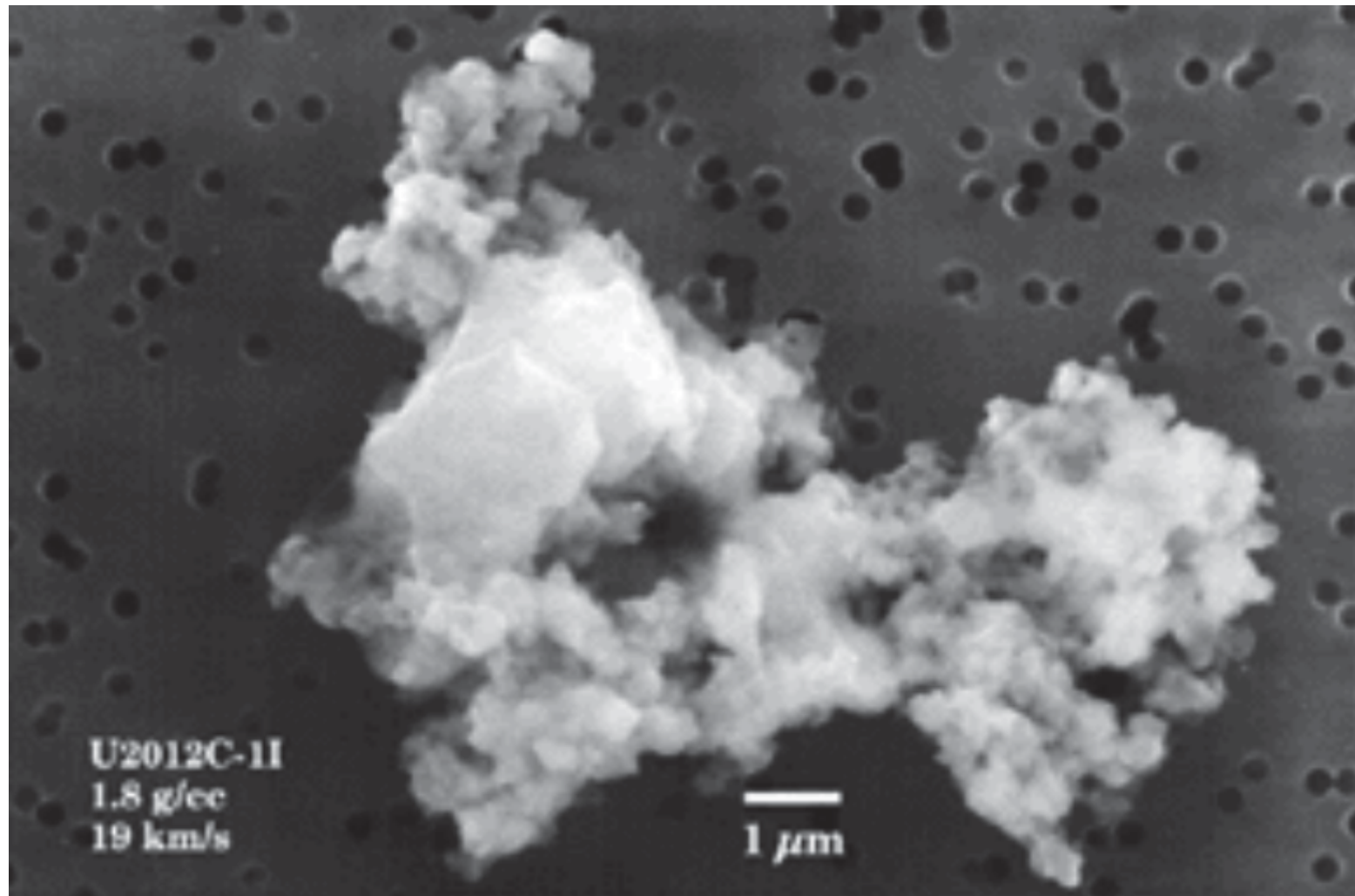
OCT 29  
2013

# Giotto Image of comet Halley

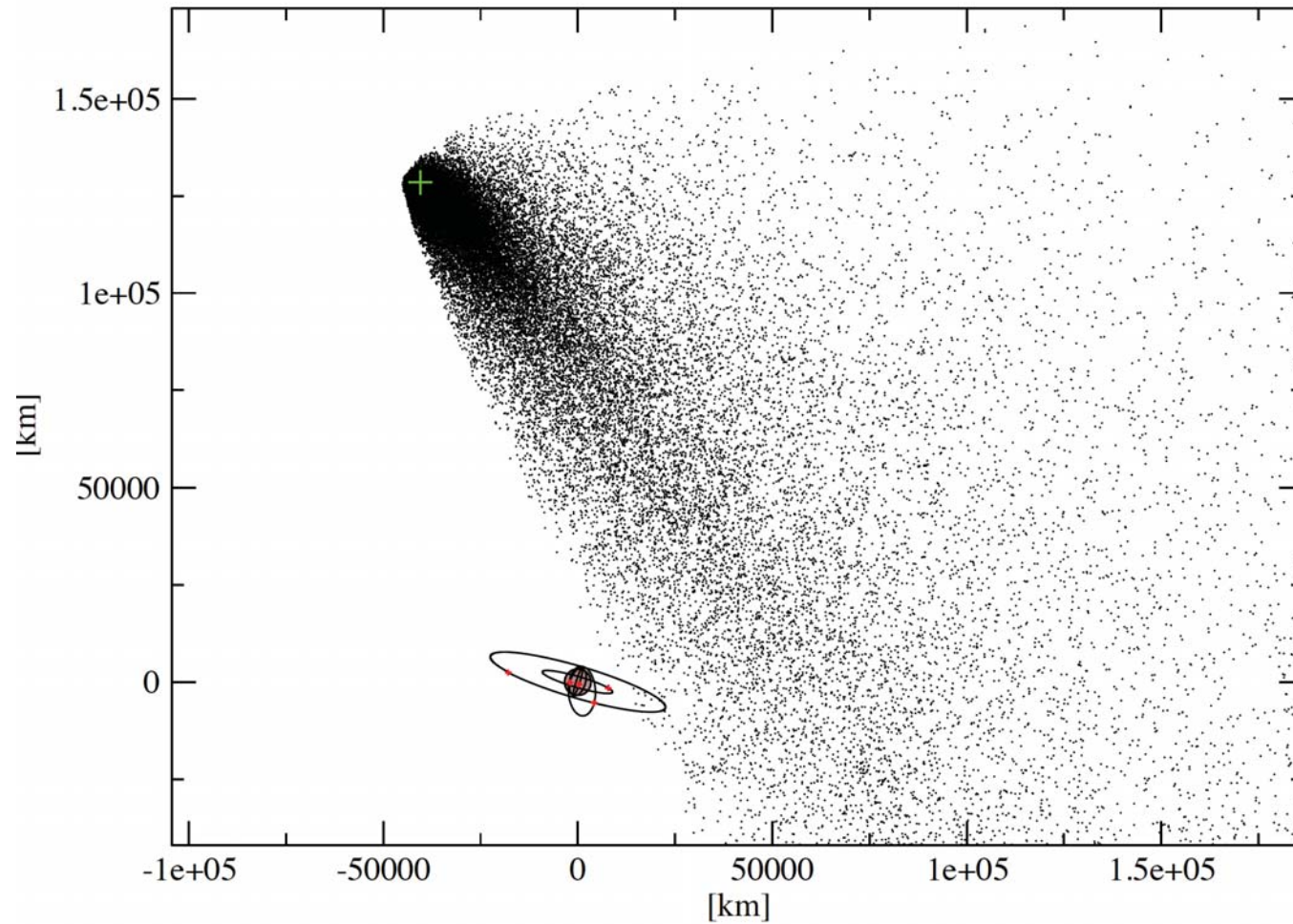


An image of comet Halley taken by the camera on ESA's Giotto spacecraft. Giotto was hit by a large dust particle and took 30 minutes to recover.

# Interplanetary Dust Particle



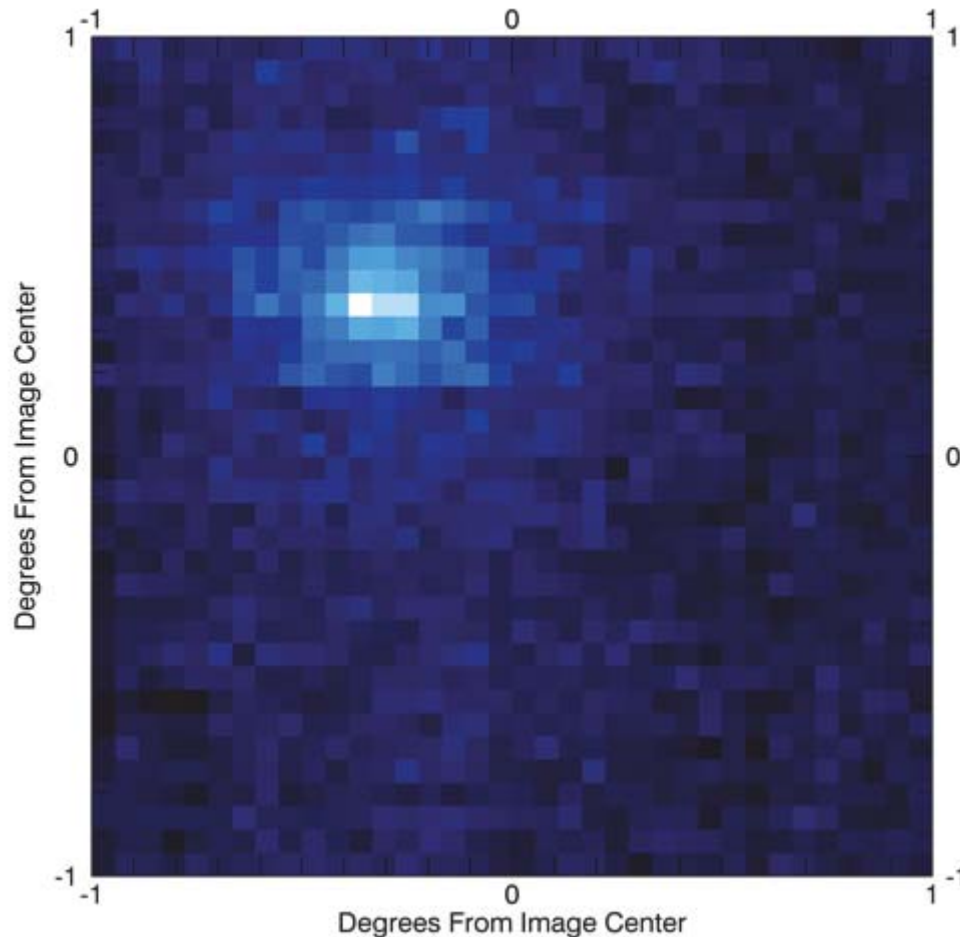
# Actually, Not So Bad



# IUVS Imaging of Comet Siding Spring

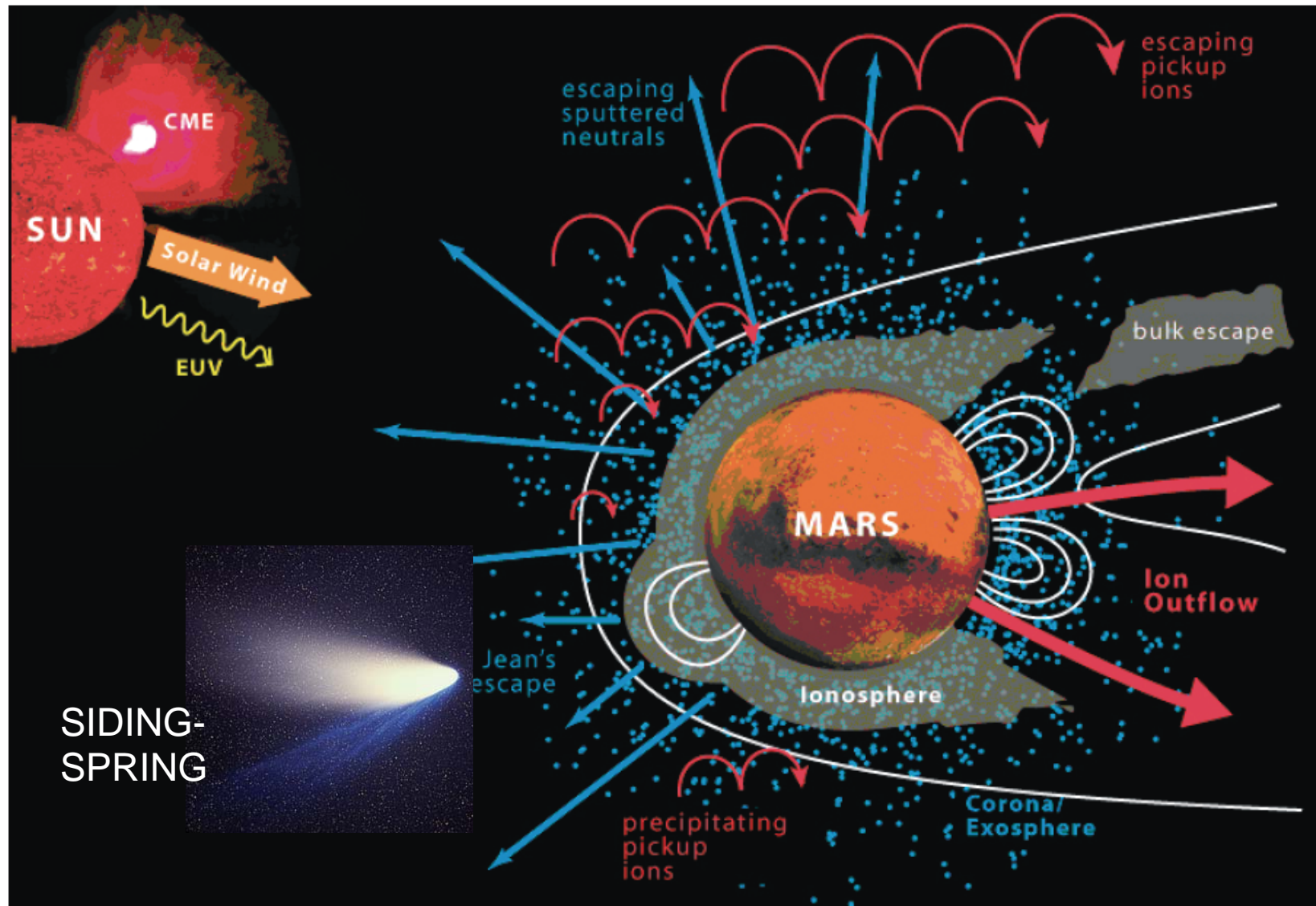


MAVEN/IUVS Image of Comet Siding Spring in H-LyA, 10/17/14

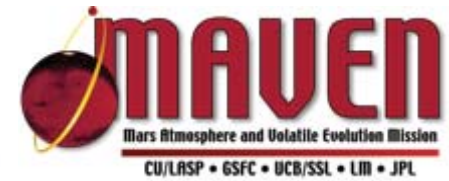


- IUVS imaged CSS in scattered solar Lyman-alpha two days before closest approach to Mars
- Reflects distribution of atomic H surrounding comet
- H detected to distance of ~150,000 km (comparable to Mars miss distance of comet)
- Gas cloud behaves differently from dust; dust comprises bulk of tail and is what is seen in visible images, so LyA images looks different from most telescopic images

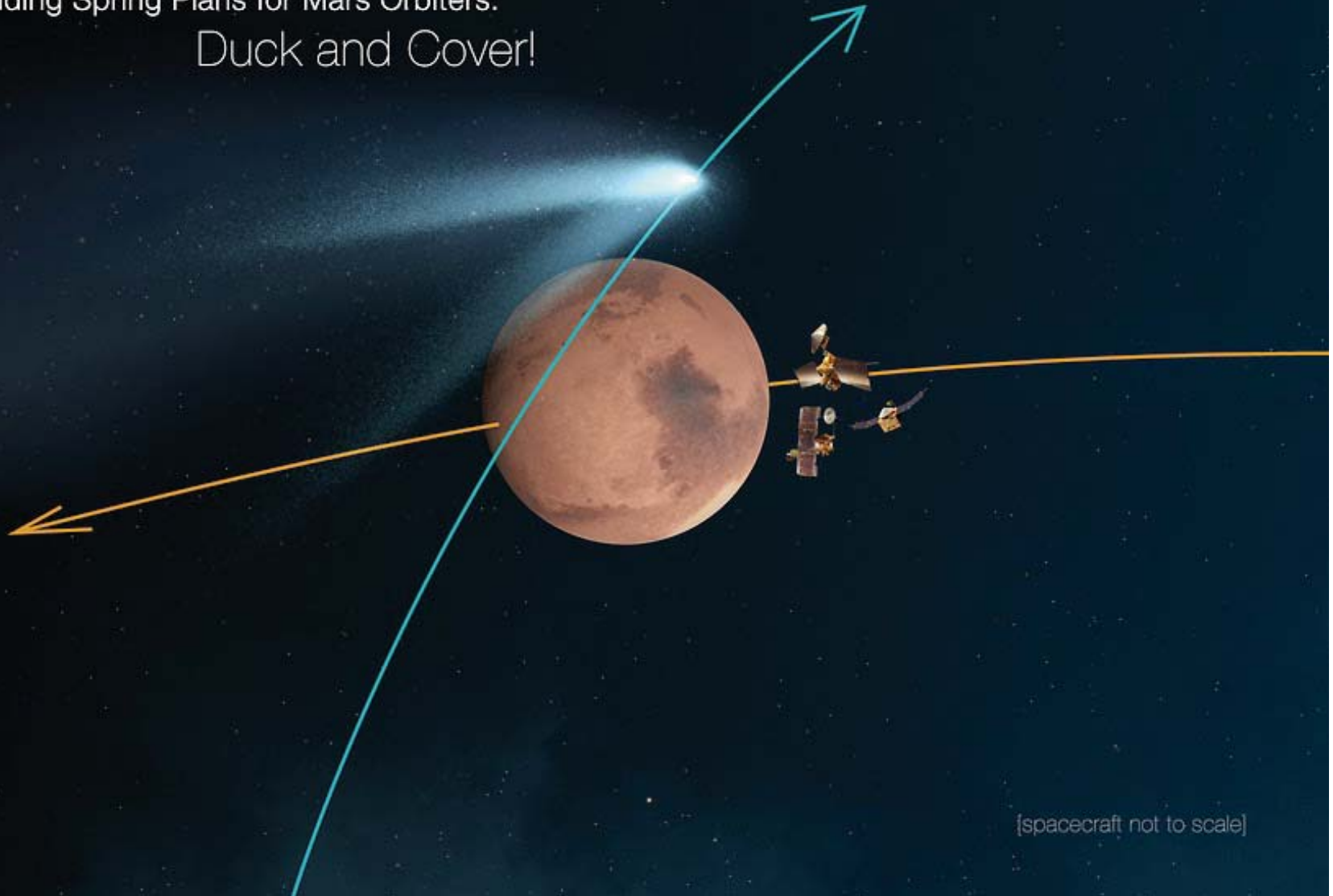
# The Opportunity



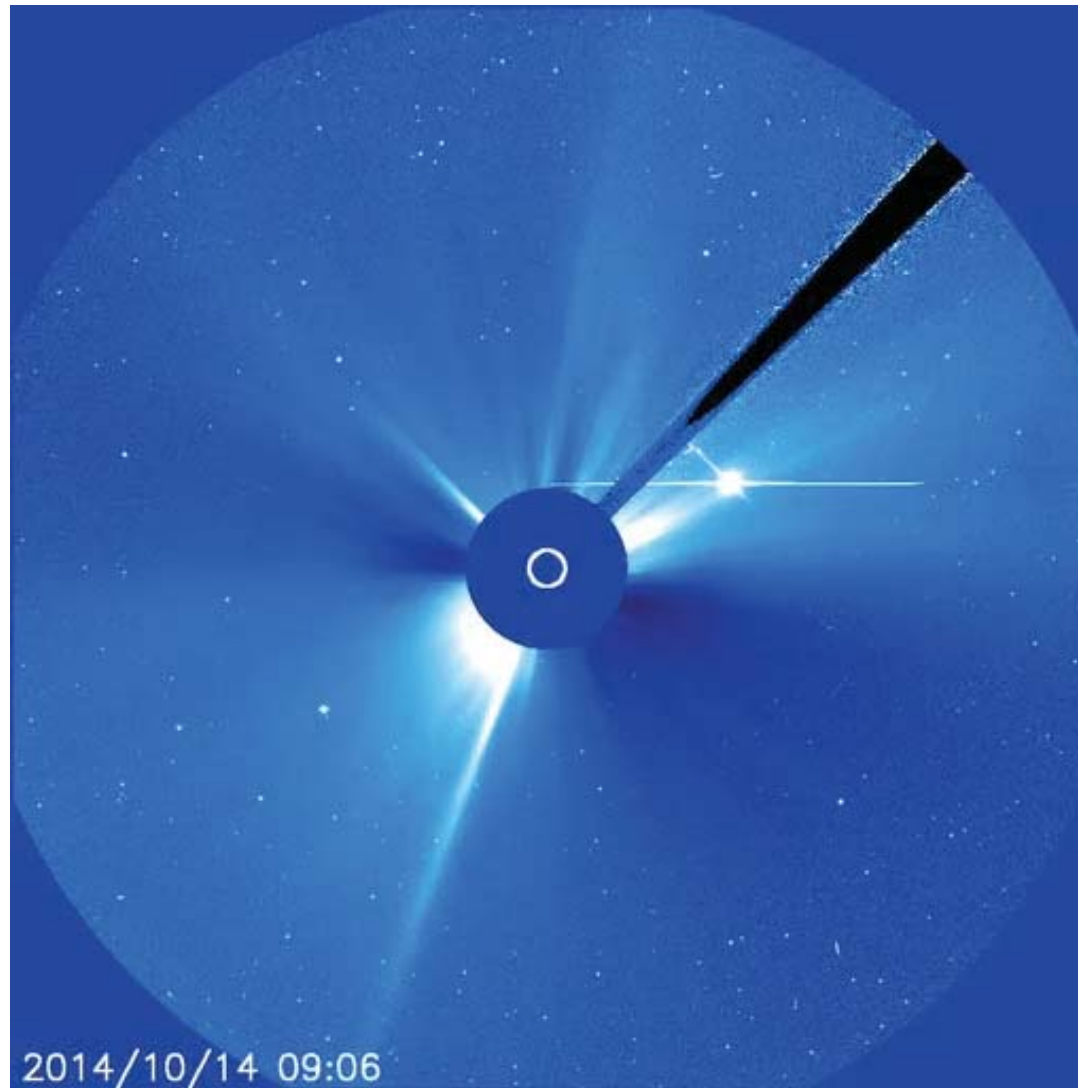
# Strategy: Duck and Turn Off High Voltage



Comet Siding Spring Plans for Mars Orbiters:  
Duck and Cover!

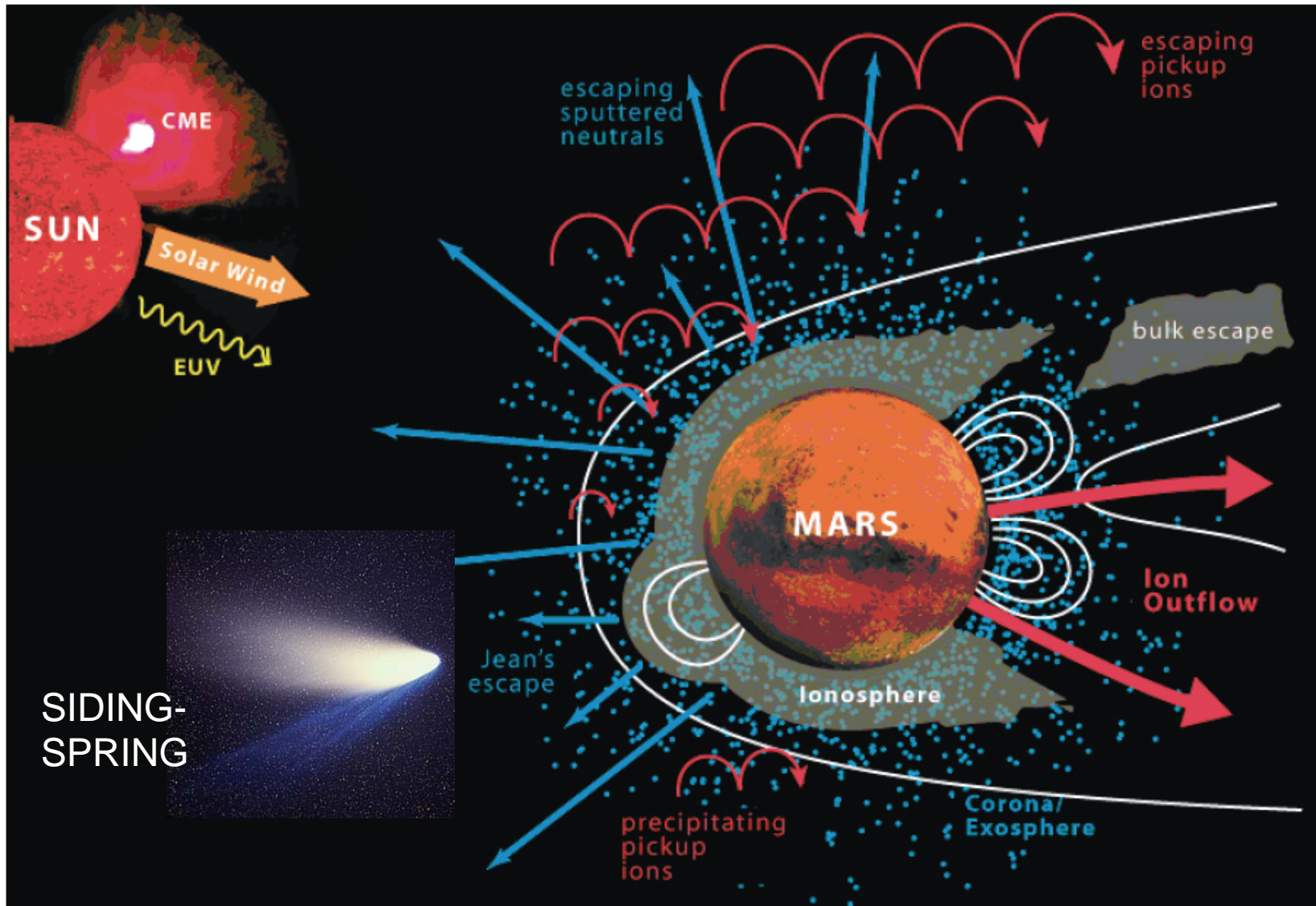


# Complications

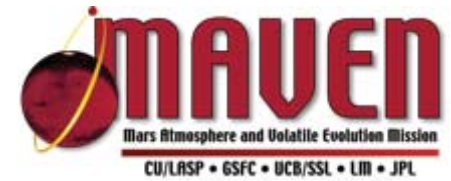


2014/10/14 09:06

# An Embarrassment of Riches



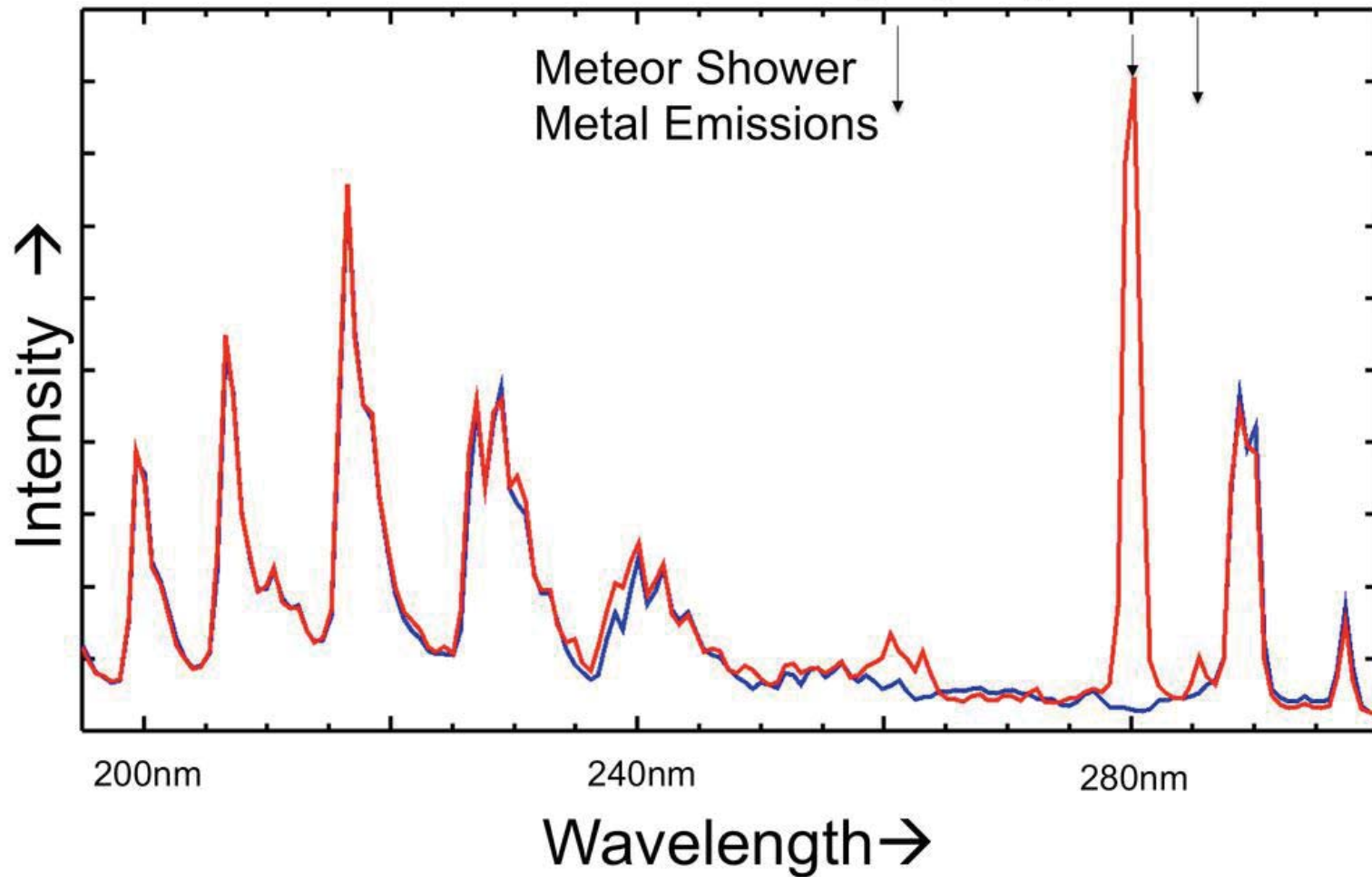
# Drama In The Control Room



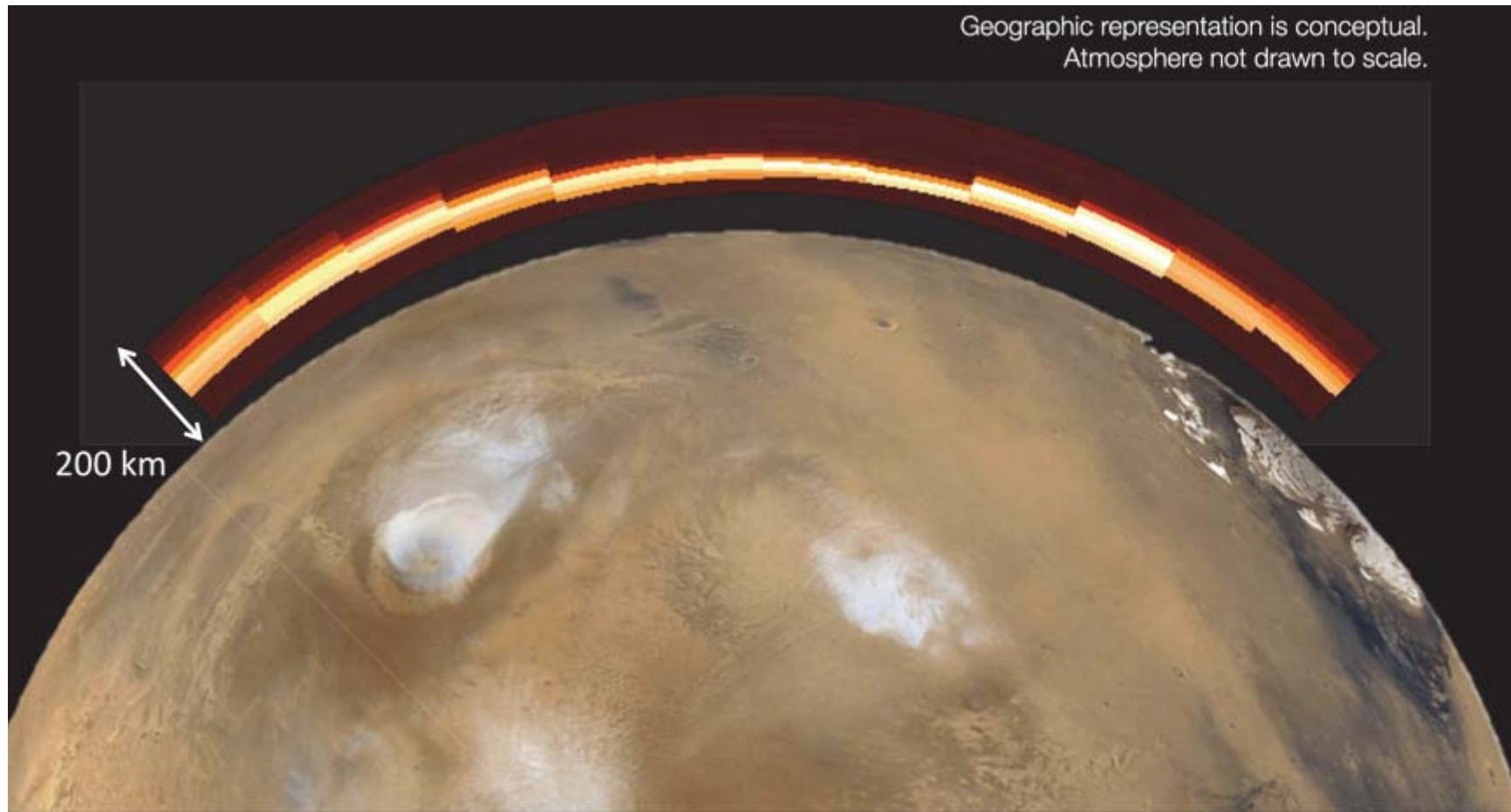
# A Peak at Results: Dust After All



## MAVEN/IUVS Spectrum of Mars Atmosphere After Comet Siding Spring

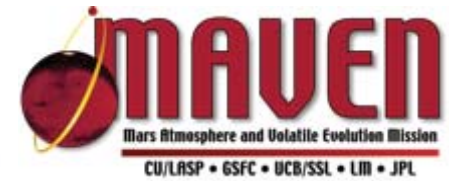


# IUVS False-Color Image of $\text{Mg}^{+2}$ Distribution

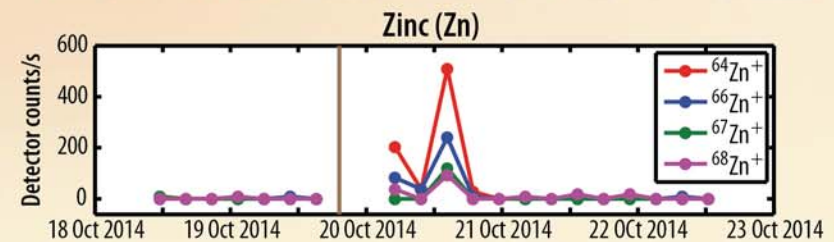
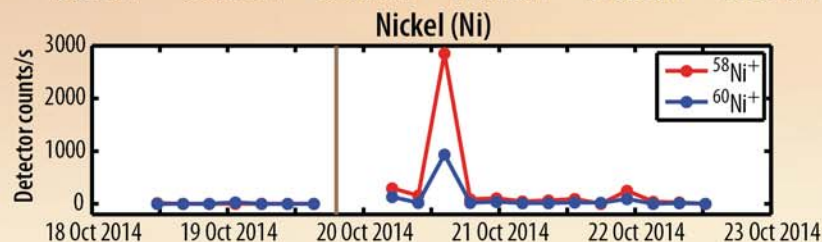
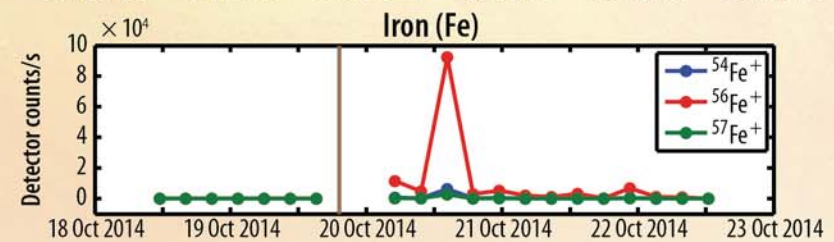
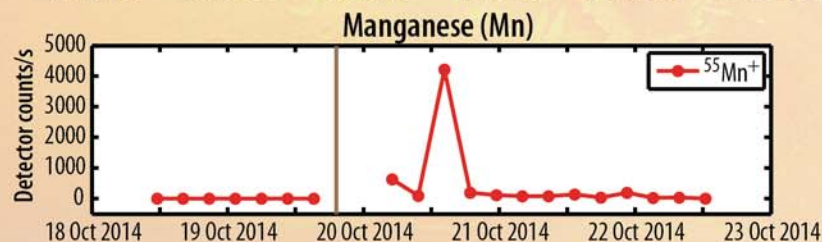
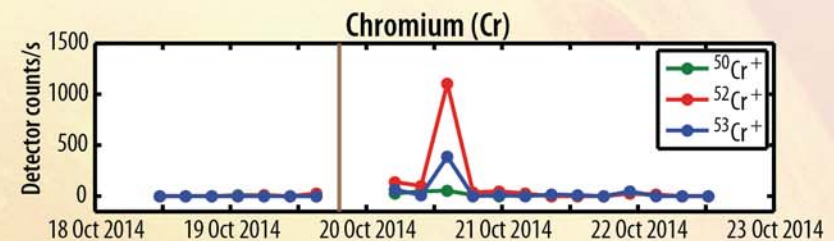
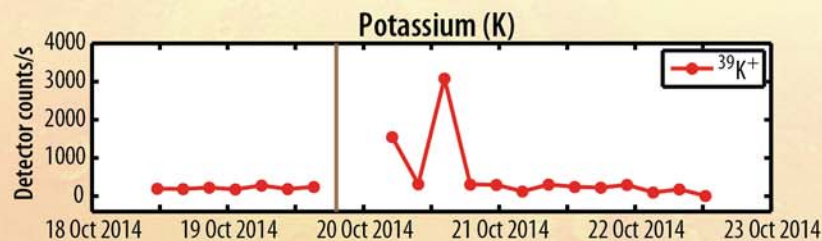
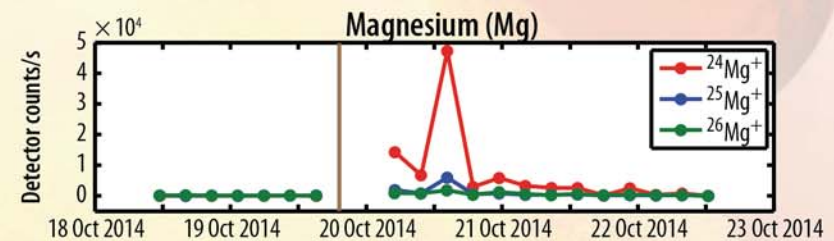
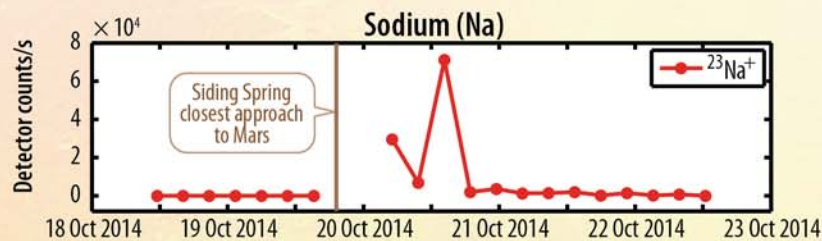


- Observed throughout periapsis pass of each orbit following comet passage
- Intensity of emissions decayed in hours to days, likely due to conversion of Mg and Fe to other forms

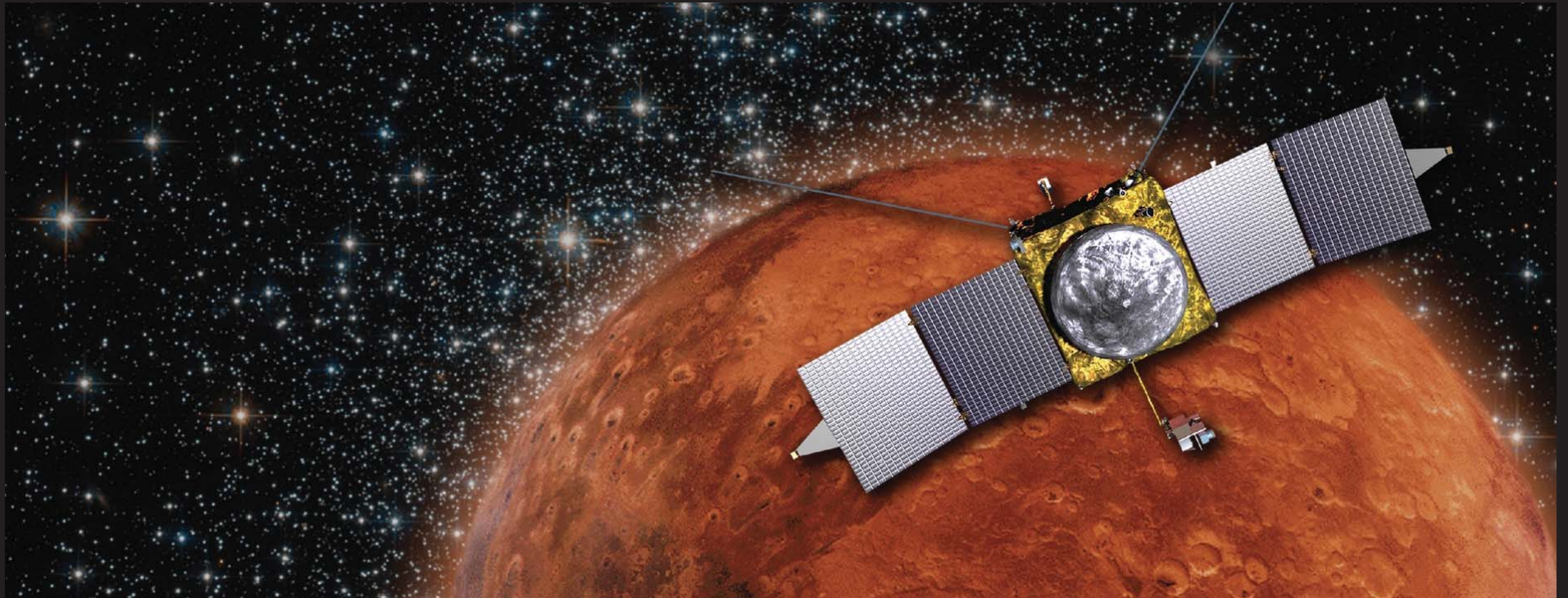
# A Peak at Results: Dust After All



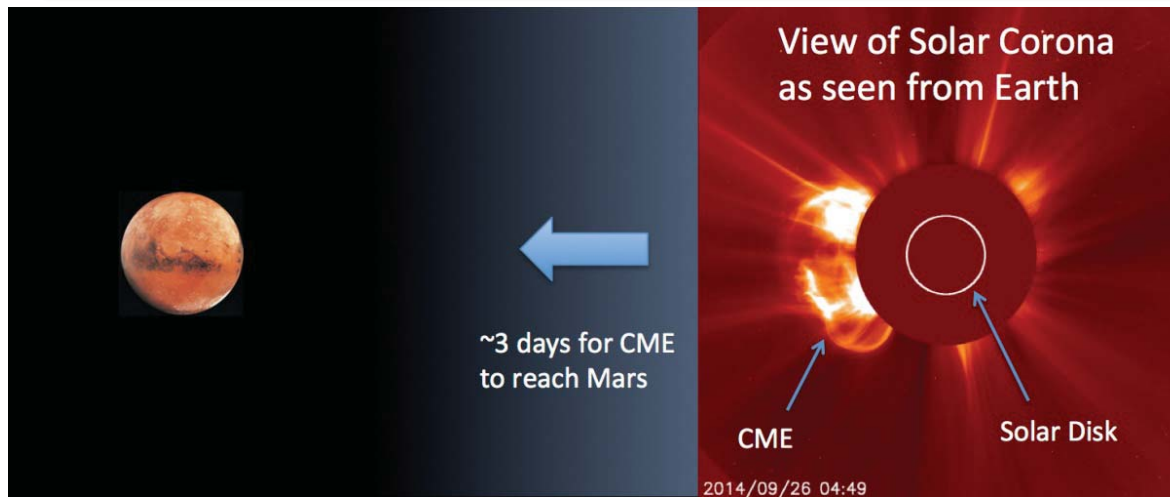
## Eight different metal ions from comet Siding Spring were detected by NGIMS



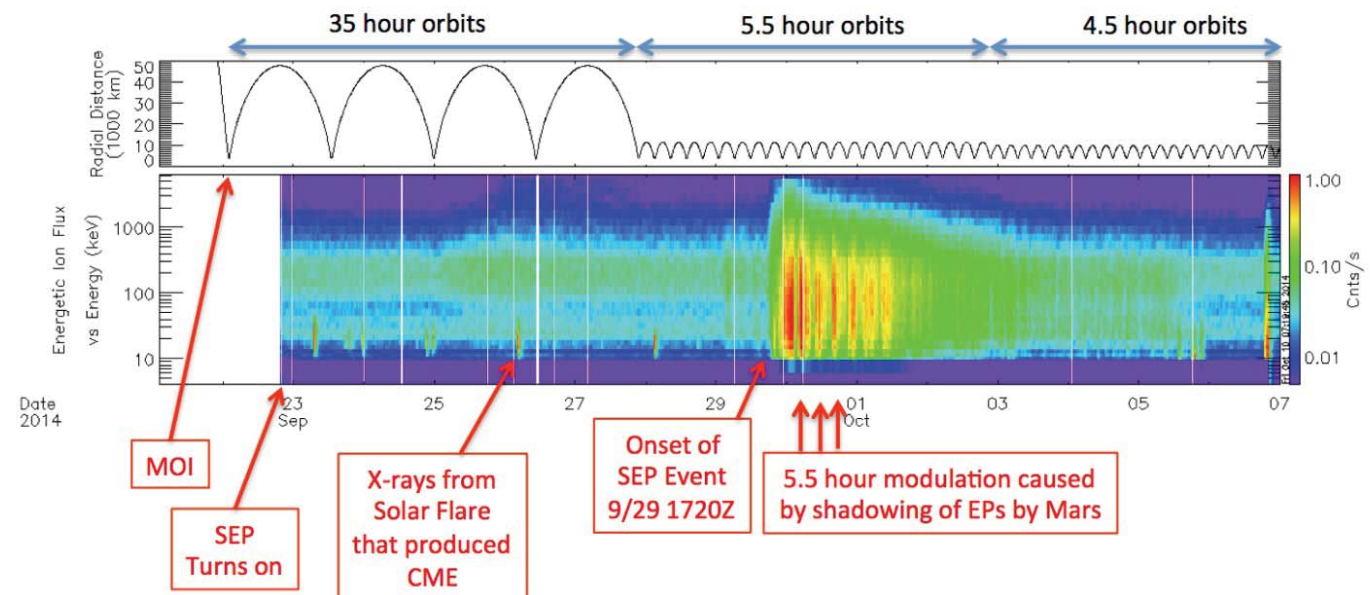
# *The Planet*



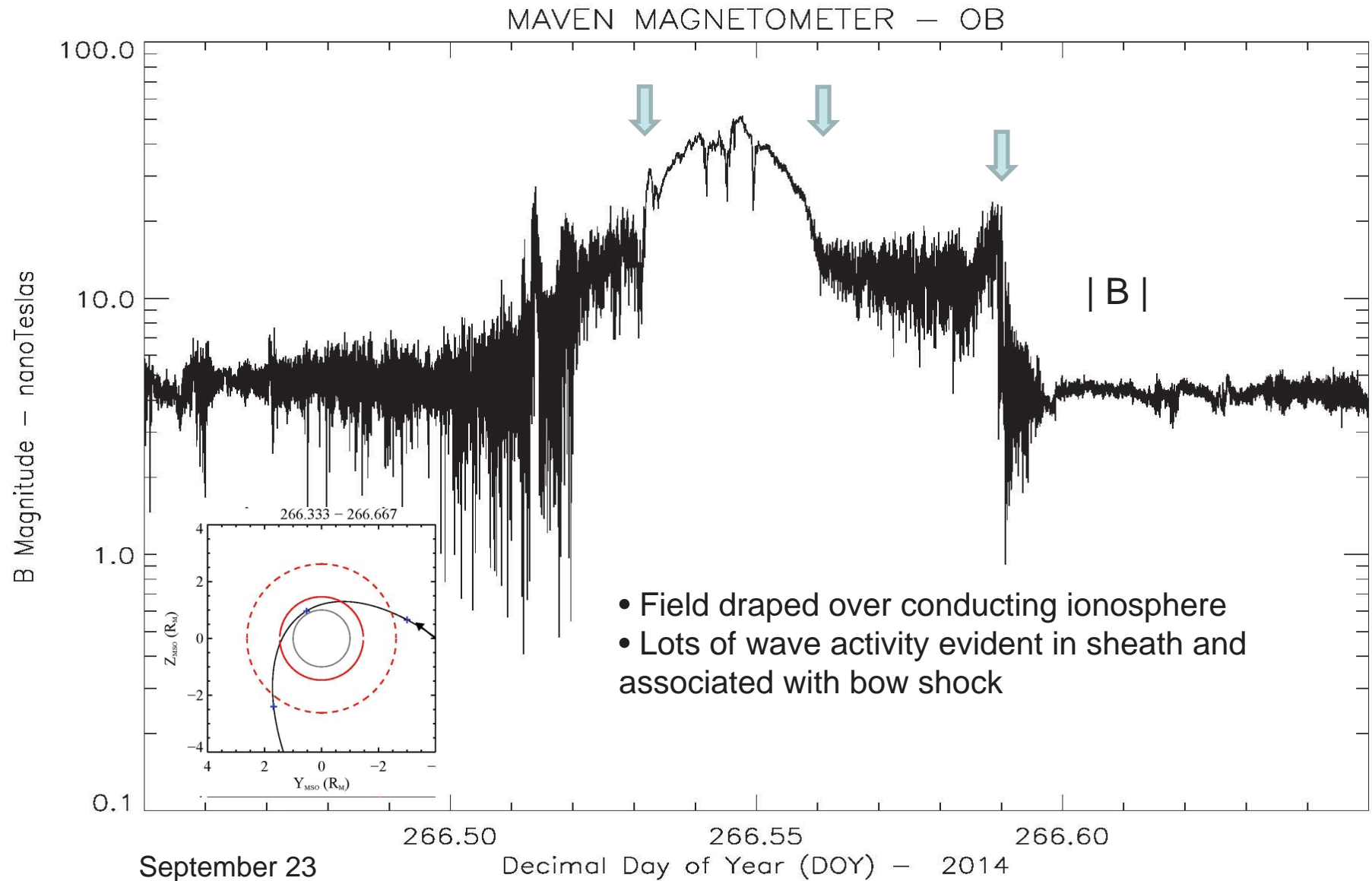
# SEP Observes a Coronal Mass Ejection (CME) Arriving at Mars



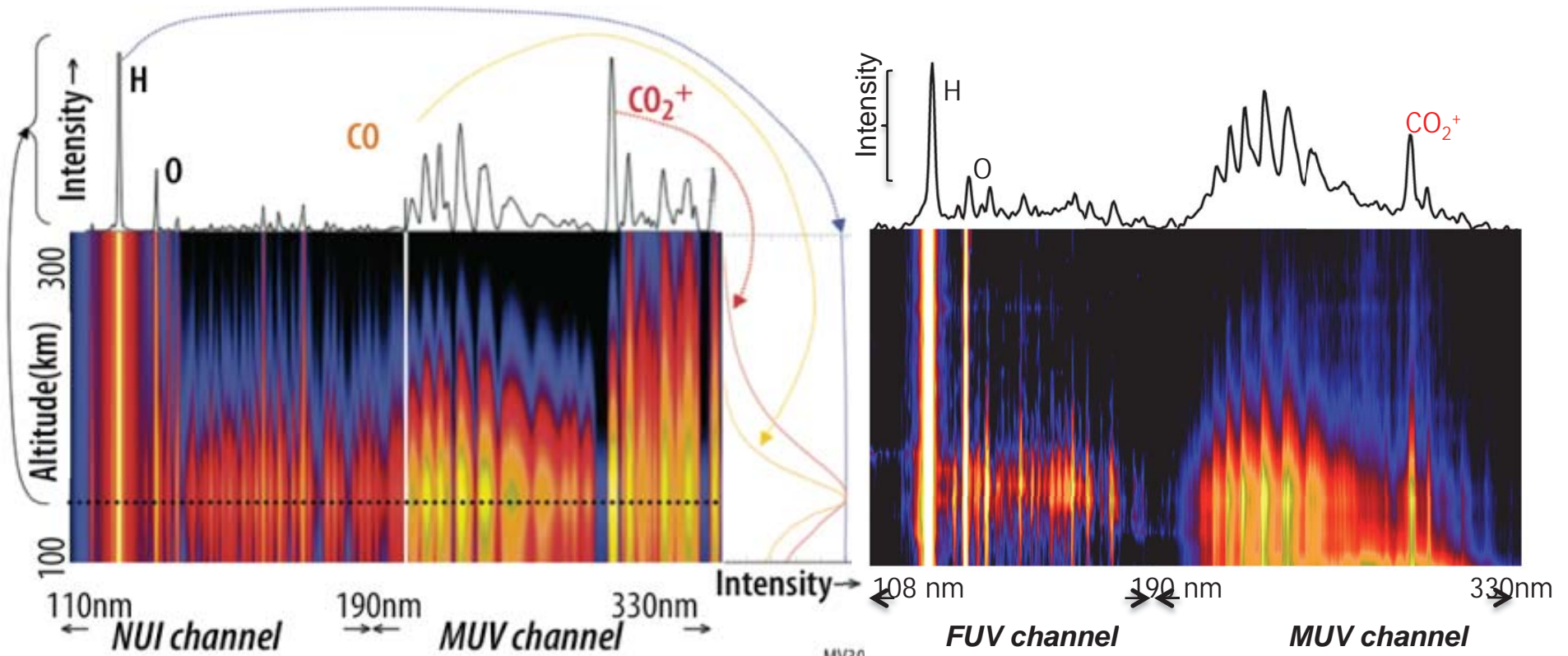
## First SEP Event Observed at Mars by MAVEN



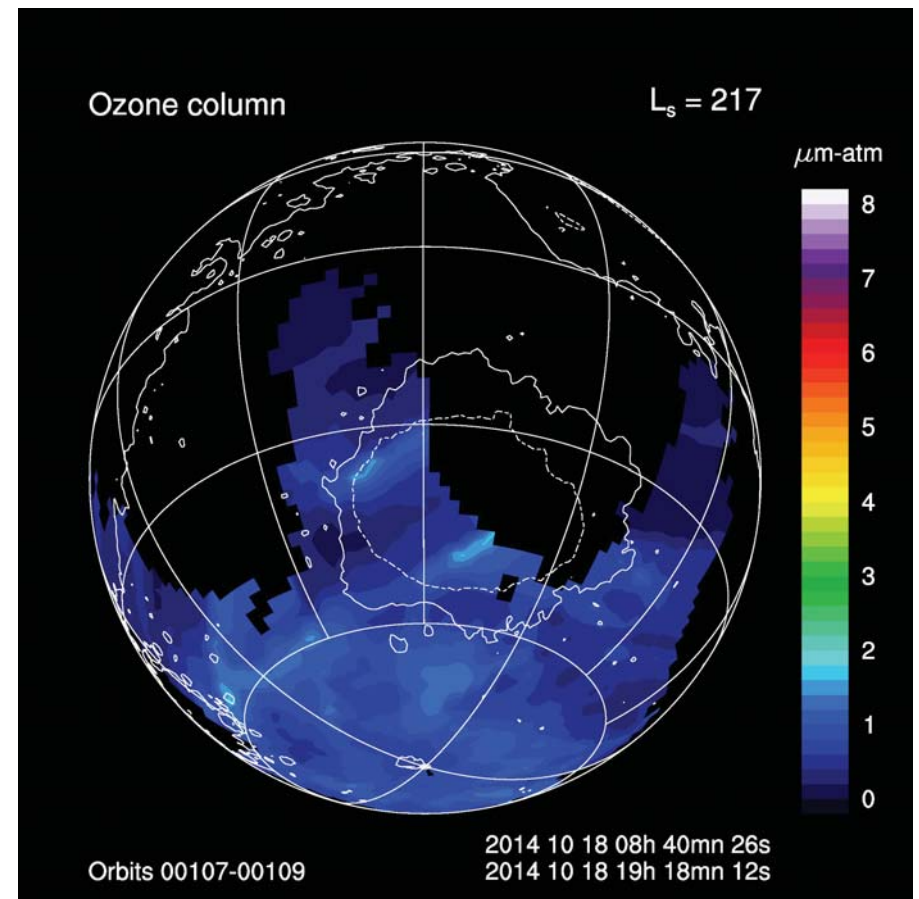
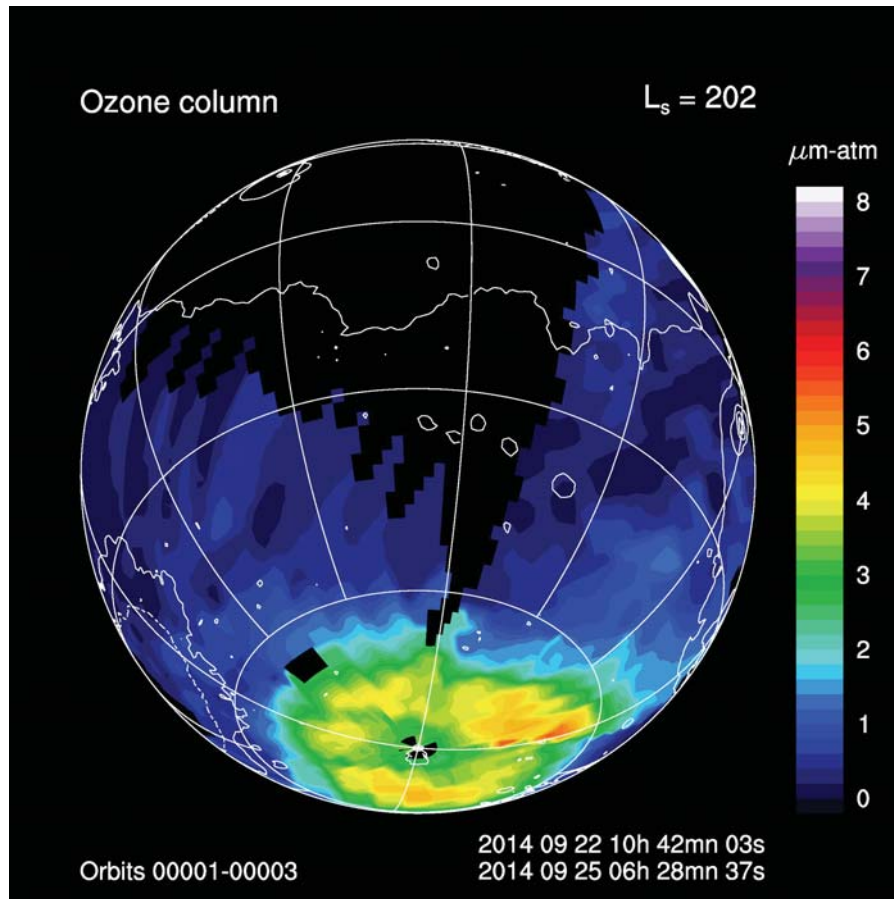
# Magnetometer Measures Interactions With Solar Wind



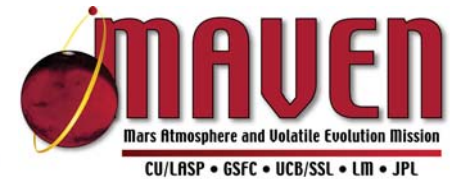
# Martian Dayglow: Determining the Upper Atmospheric Composition



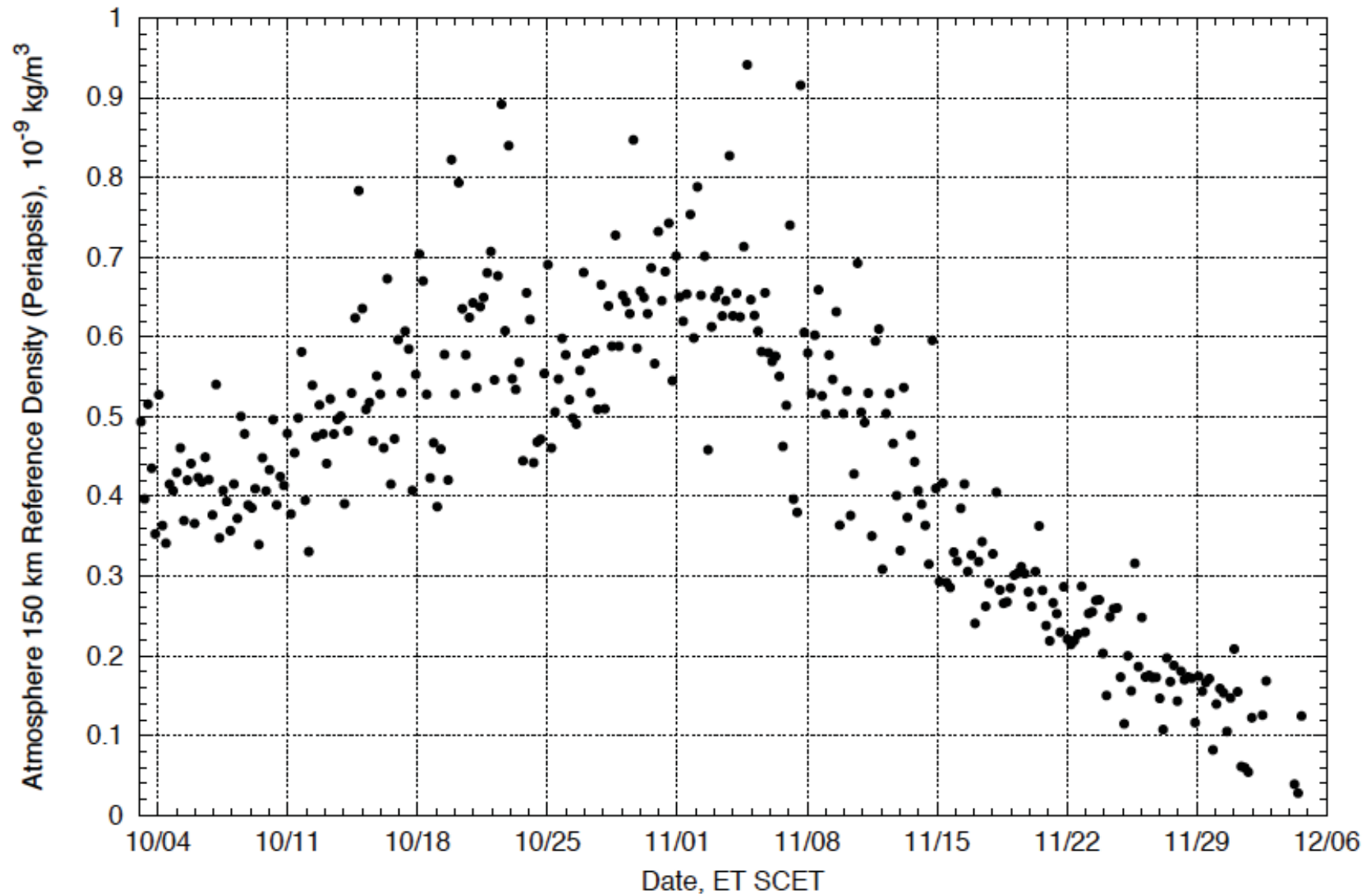
# IUVS Maps Changing Mars Ozone



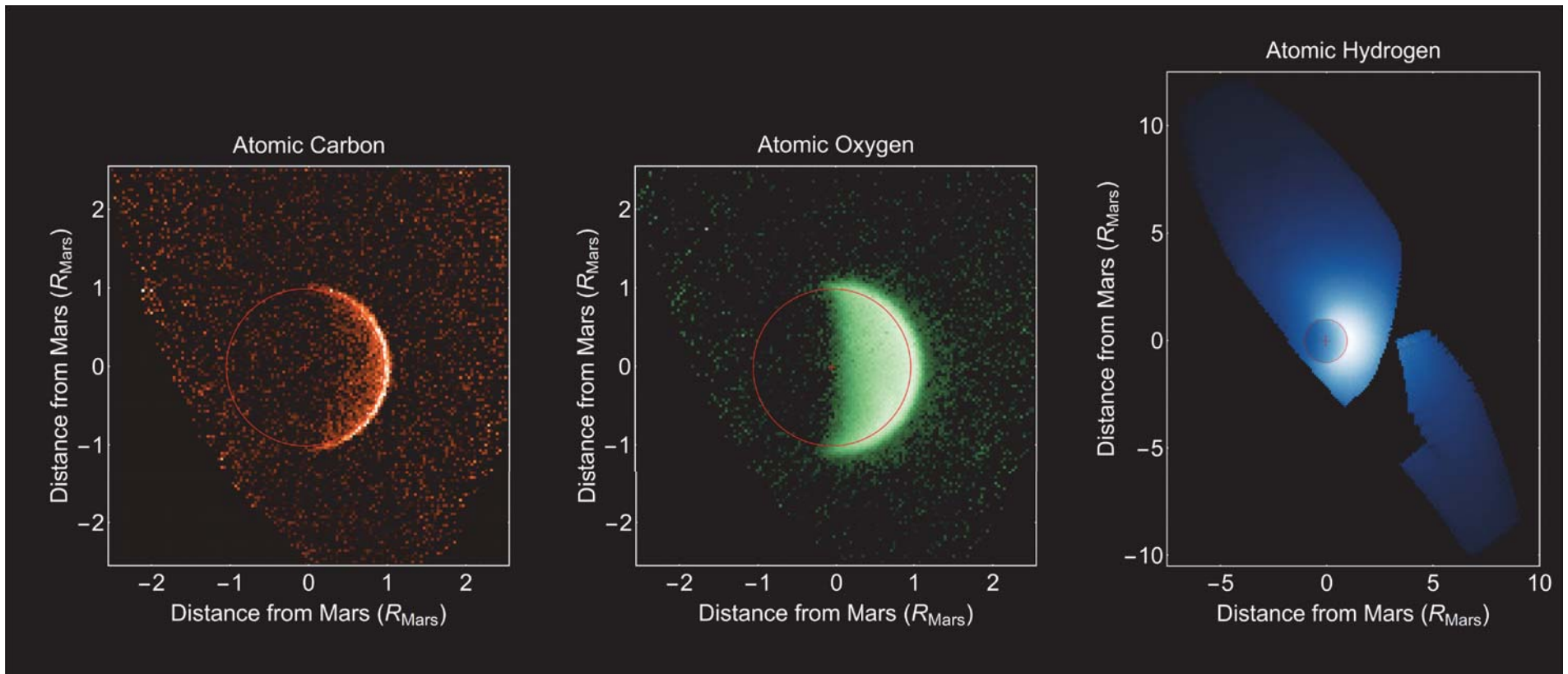
# Atmospheric Density at Orbital Altitudes Shows Seasonal Trend



MAVEN Orbit Phase - Reconstructed Trajectory



# IUVS Observations of Components of $\text{H}_2\text{O}$ and $\text{CO}_2$ on Their Way to Escaping



# NASA's Mars Exploration Program

## Launch Year

Operational / Recent

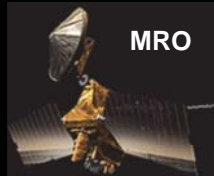
2009

2011

2013

2016

2018 & Beyond



MAVEN

MER



Mars Science Lab



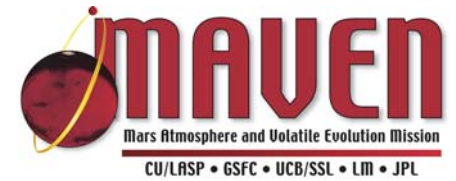
InSight



Mars 2020



# MAVEN Impacts All Ages



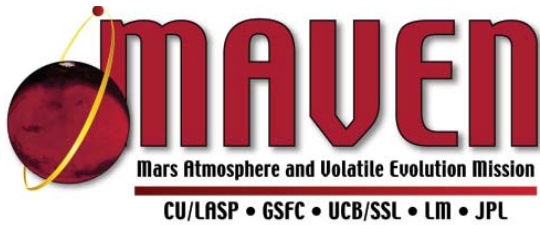
MAVEN "Send your artwork to Mars" contest, 2013



LASP Clean Room Tour, 2012



Little Miss MAVEN, Halloween, 2014



- ***MAVEN launched on schedule and under budget!***
- ***It arrived at Mars in September and began its science mission in November!***
- ***Just beginning to get science results – stay tuned!***

***Go MAVEN!***

**[Continue to follow us on Facebook and Twitter: MAVEN2MARS]**

**[Join MAVEN and Exploration Station – 1-5 p.m. today for hands-on exploration for the family.]**